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MEASURING OF ORTHODONTIC FORCES

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REVIEW ON TOPIC RELATED TO MEASURING OF ORTHODONTIC FORCES

THE dentist, especially the orthodontist, is sooner or later confronted with a desire to become familiar with the problem of measuring orthodontic forces. A review of investigations in this field is supplemented by the author's own attempt to solve the intricate problem.

In order to have a broad conception of this particular field of orthodontics and its clinical application, one should become familiar with a number of subject matters closely related to the subject of orthodontic forces. The following topics are of particular interest:

1. Metallurgic consideration of materials, heat treatment, and soldering.
2. The orthodontic force, its intensity and application.
3. Measuring forces of arch wires, finger springs, and rubber bands.
4. Biologic facts.
5. Properties of the periodontal membrane.

Literature.—When a dentist is confronted with the task of constructing an appliance, he has many problems to consider. One of the first prerequisites should be a firsthand knowledge of materials of established physical properties. Lack of knowledge of orthodontic materials often results in failure in the construction of intricate orthodontic appliances. The same thought was expressed by Korkhaus, who complains of the disappointing experiences with modern appliances. He specifies that besides knowing the quantitative chemical composition, one should know how the alloys are manipulated in manufacturing, and their physical properties.

The physical properties disclose how a metallic alloy behaves under pressure, pull, or bending, and if the alloy is hard or soft. Further, they disclose whether the material, when subjected to stretching, resumes its former shape

after the stress is removed, or remains permanently deformed. Materials may be subjected to great deformation, like rubber. Such a material is called elastic. If a material changes its shape readily under a small load, it is ductile. Should it break when stretched under a small load, it possesses low tensile strength (low solidity). Brittleness is manifested when the material breaks at the slightest bending, flexibility if it can be bent considerably without breaking, and endurance if subjected to frequent bending without breaking.

Properties such as softness, malleability, and brittleness are of common nature and depend upon the manufacturing process; others are determined by the experimental apparatus. Some properties of the metallic alloys are influenced by treatment with cold or heat. This is due to a variety in the structural arrangement of the metallic crystals. Modern scientific methods enable us to examine the structural arrangements under the microscope, and to evaluate their mechanical properties with the aid of special apparatus. Properties may be determined also by the thermical method, in which the heating curve is employed.

Heat treatment is not sufficient to disclose all the properties of an alloy. Working the material, for instance, greatly influences the density and compactness of the structural arrangements. Every time the alloy is "cold worked" there is an increase in its solidity (hardness) and its brittleness, and a decrease in its malleability, and consequently, workability. If the material is rolled or stretched, the crystals are stretched and finally destroyed. In the same conspicuous way, the structural arrangement may be influenced by the temperature. It is known that steel, heated to red hot and then slowly cooled, becomes soft. If heated again and then plunged into water or oil, it turns hard. To obtain good workability of gold alloys, the process described above for the treatment of steel is reversed.[1]

Williams pointed out problems in the manufacturing of orthodontic wires. "Pipes," which are fissures appearing at the extreme upper portion of the rod being cast, through which gases escape when the metal solidifies, cause the resulting product to be heterogeneous. Another condition called "cuppy wire" may be detected when a wire is fractured and one end of it takes the shape of a cone and the other of a cup. Such wire is poor in tensile and torsional strength. The defectiveness is due to a segregation of the metals and overdraft. To overcome such defects and to produce a wire that is homogeneous, devoid of blow holes, and functions perfectly, the temperature during the manufacturing of the wires must be controlled by pyrometers.

He enumerated several properties that a wire should possess to be practically employed by the orthodontist. The wire should be springy and stiff and must retain that springiness after being soldered. To insure successful soldering, it should be free from oxidation. It should have high tensile strength after annealing because the metal is annealed at the point of soldering. It should be torsional and resistant to a large degree of bending without breaking.

In experimenting with wires of noble metal, Williams discovered that during the process of plunging the hot wire into cold water, there is a 12½ per cent loss in elasticity and a 12 per cent loss in strength. But, when the

wires were reheated to cherry red and cooled in the air, they regained their strength and elasticity. This air cooling treatment had a decided tempering effect. However, if the air-cooled wire was boiled in pickle to remove the oxide on the surface, there was a loss of 6 per cent in elasticity and a loss of 2½ per cent in strength, due perhaps to friction at the fixed point. To restore any possible loss in elasticity and strength from mere boiling in acid, the wires should be tempered, whereby they gain all their lost strength and elasticity and an additional 35 per cent in strength. If such a tempered wire is subjected to boiling in acid, there is again a 7½ per cent loss in elasticity but no apparent loss in strength.[2]

He illustrated a very fine distinction in the metallurgic requirements of the orthodontist by giving an example of what happens to a rod of metal fixed between two jaws in a tensile testing machine, and also published the stress-diagram of Fahrenwald, who experimented to produce a metal suitable for orthodontic use. Rhodium, iridium, palladium, platinum, silver, and gold were used in his experiments. He states that Fahrenwald found that copper and nickel add considerably to the tensile strength.[3]

Williams also deals with a number of reasons for failures in orthodontic treatment when using precious metals. Failures may result from the use of wires of exceptionally high tensile strength and low ductility, from the hardening heat-treatment, either deliberately performed or as a result of soldering, from an excess of heat in soldering operation, from fatigue through manipulation by the patient, from manipulation of arch wires while hot, and from the use of defective materials.

In the preliminary investigations of orthodontic materials, it was found that, on the whole, ultimate tensile strengths were comparatively low. It also was found that either by change of the formula or by means of the prescribed heat treatment, tensile strength could be increased enormously, sometimes to the extent of 75 to 80 per cent. However, the investigations conducted in cooperation with Mershon have disclosed the fact that exceptional hardness or high tensile strength is not desirable. Exceptionally hard wire of high tensile strength and low ductility is apparently not only physiologically incorrect, but metallurgically hazardous because such wire can be subjected to permanent bends or repeated stresses only at the great risk of a complete fracture. A close, practical study of orthodontist's technique reveals the fact that a hardening heat-treatment is not the cure for breakage evils, but in fact, may well be the cause.[4]

Taylor explained the results of research on dental materials conducted by the National Bureau of Standards in cooperation with the American Dental Association. The replies to questionnaires sent to a selected group of practitioners, concerning manipulation of wrought alloys, indicate a great need for improvement in the methods of handling the wrought alloys in the laboratory. These methods are many and vary from the use of annealed wire without any heat treatment for hardening the alloy after the forming and soldering operations, to the similar usage of hard-drawn alloys. In the intermediate groups, methods of annealing hard-drawn wire vary and include brief heating, heating to a red heat, and then cooling, electrical annealing and quenching,

and furnace annealing for several minutes followed by quenching. Methods of hardening are equally varied and range from complete absence of any treatment by cold-working and bending, to heating to red heat and air cooling, and to a variety of tempering processes which consist of exposing the alloy to specified low temperatures for a period of anywhere from ten minutes to an hour by means of slow cooling.

In the consideration of these methods in their relationship to the probable effect on the properties of the gold alloys, the conclusion most logically derived is that the qualities of the alloys in general use must be excellent to withstand so many varieties of abuse and still give satisfaction.

The diversity in the methods described indicates very clearly that much work must be done to develop uniform, simple, and practical methods of treating orthodontic appliances to insure the best utilization of the desired properties of the alloys employed and to eliminate many of the present errors. It is safe to assume that the principal role to be played by the orthodontist in the solution of this general problem will be application of metallurgically sound methods of manipulation and heat treatment in the production of his orthodontic appliances.[5]

HEAT TREATMENT

Heat treatment is an important metallurgic phenomenon manifesting itself in many alloys. This property of alloys is especially useful in construction of appliances as by heat treatment some wires can be made soft and ductile or their strength and resiliency increased.

According to Brumfield, the physical properties of dental gold indicate that it is possible to raise the proportional limit of high grade wires as much as 75 per cent by the proper heat treatment.[6]

Williams advocates that every orthodontic laboratory have an electric furnace with absolute heat control since soldering, annealing, and other forms of heat treatment of materials play such an important part in construction of appliances.[2]

Taylor relates that Coleman performed softening treatments on wrought alloys by heating the alloys to 700° C. (1292° F.) in the furnace and subsequently quenching them in water. However, such softening treatment is not sufficient to remove entirely from all wrought alloys the work hardness imparted by drawing. The time required to soften various alloys thoroughly is being determined. Neither does the practice of "flaming" alloys until they are red hot and then allowing them to cool in air remove all work hardness from the alloy. The forming operations performed with gold wires should be carried out with well-annealed samples, and the completed appliance should be hardened by subsequent heat treatment, if certain possible conditions in the metal are to be obtained. Partially softened wires are, of course, less subject to breakage than the original hard-drawn wires, but the bending operations leave in the partially softened wires highly stressed sections, which should be relieved by heat treatment. In general, alloys which have been softened may be hardened by heat treatment, which consists of slow cooling through the temperature range between 450° C. (842° F.) and 250° C.

(482° F.), or by heating the alloy for various periods of time at temperatures between 250° C. (482° F.) and 450° C. (842° F.), followed by quenching. The first method is that commonly recommended by manufacturers at the present time, as it may be performed without careful control of temperatures by an operator. The hardening effect is dependent upon the rate of cooling, and some types of alloys tend to become excessively hard and brittle if the hardening period is prolonged.

A furnace which appears to be satisfactory for common dental use has been designed as a result of the combined efforts of the American Dental Association and the Bureau of Standards.[5]

Paffenbarger, Sweeney and Isaacs recommend that orthodontic wrought wire be heat treated, which consists of heating and quenching to obtain a wire that will possess low tension, low elasticity, and high elongation for easy manipulation, reheating, and slow cooling the finished appliance to gain high tension, high elasticity, and medium elongation, which are desirable in orthodontic practice. By inaccurate heat treatment some wires' degree of elongation is reduced to almost zero, and the wires become brittle. Paffenbarger, Sweeney and Isaacs advocate oven cooling, where wires may be cooled at a uniform rate, or heating the appliance in convenient equipment, such as a salt bath. KNO_3 and $NaNO_3$ mixed in approximately equal proportions by weight and melted to a straw colored liquid at approximately 210° C. (400° F.), a Bunsen burner, a tripod, and a heavy metal pan for holding salts, and a short-stemmed mercury thermometer which registers up to 400° C. (750° F.) are used in the process. Precaution should be taken that appliances are dry, as organic materials, such as waxes, explode easily.

An oven-cooled heat treatment assures the user that the alloy will not become brittle with the indiscriminate heat treatment it often receives in practice. An alloy which is satisfactory after oven-cooling should withstand such treatment as high curing temperature, baking in investments, and slow cooling from soldering operations. It follows that any wire which withstands this oven-cooling process will give satisfactory service in practical application. In addition, manufacturers' data on the specific temperature and time of exposure to that heat necessary to assure the most satisfactory results for the purpose at hand would be of great value. Such data aid the dentist in heat treatment and also qualify the manufacturer's product for maximum service. Elongation particularly is affected by oven-cooling. Selection of approximate aging for a definite period of time makes it possible, in some wires, to hold the tensile strength near the oven-cooled value and at the same time to double the degree of elongation, producing a most desirable result. The dentist speaks of a wire having such properties as being "tough."

Some criticism has been directed toward heat treatment. It is true that less than 10 per cent of the dentists heat their own appliances, but many of that 10 per cent are neglecting a refinement which has many distinct advantages.[7]

SOLDERING

Soldering itself is an operation which requires the utmost care and skill. Most wrought alloys are seriously injured if overheated, particularly alloys

which have a low fusion point and which are susceptible to age hardening by heat treatment. When wrought alloys are heated to temperatures close to their fusion temperature, their normal fibrous wrought structure is changed to a coarse crystalline structure, and when the alloy in this state is subjected to a hardening heat treatment, it will become brittle and is subject to breakage if bent.

In investigating the characteristics of gold solders under the microscope, Williams came to the conclusion that the 22 karat solder seemed to be the most ideal. This type of solder develops only a few blow holes and is greater in ductility. The lower karat solder, for example the 14 karat, is more brittle and develops more blow holes which may cause breakage. As the penetration of solder into the parts to be joined is undesirable, the metals should be removed from the flame immediately when the solder begins to flow. Every solder should be about 200°-260° C. (400°-500° F.) lower in fusing point than the parts to be soldered.

During the investigation some joints were welded and the resulting conclusion indicated that welded joints are not adapted to the type of strain to which orthodontic wires are subjected, because in fusing or near fusing a metal its crystalline structure is changed to that of cast structure, whereby the metal is robbed of desired qualities which are developed only by cold working, as in being drawn, etc.

Williams also recommended a solder specifically designed for orthodontic use. Since prolonged and excess heat in soldering produces embrittlement in both wire and solder, and since the solder must be used at the point of attachment of the auxiliary springs, it is logical to assume that the solder should be of high karat, yet of low fusing point and reasonably low surface tension.[2]

Paffenbarger, Sweeney and Isaacs recommend heating and quenching the wire first, so that it can be easily worked. After forming, soldering should be done at the lowest possible temperature and the springiness restored by proper heat treatment.[7]

Abelson pointed out the most frequent source of difficulty in the application of auxiliary springs—the breakage at the point where the auxiliary spring is soldered to the body wire. At that point he advocates the use of a one and one-half turn of helical spring, which will effect a distribution of the fatigue effect of the metal over a much larger area.[8]

Brumfield attributes much success in soldering to speed. Soldered joints are weak points and should not be located at points of maximum bending or stress. They should be as thin as possible. The thinner the soldered point is, the stronger it will be. Also the smaller the area over which the solder is spread, the better, as less of the original material has been weakened by alloying with solder.[6]

Aderer, too, is of the opinion that much of the breakage of delicate wires on appliances is due to the use of excess soldering material and excessive heat. Deterioration of delicate wires occurs in proportion to the excess of solder employed. Small pieces of solder (less than half a millimeter square) should be used in joining half round posts and finger springs to the arch wire. First,

the fine wire is flattened with a file to provide a better contact; then, the heavier wire is heated; and finally, the fine wire is bent over the arch wire. He recommends a fine camel's hair brush for carrying tiny bits of solder into place and a liquid flux to be used in soldering.[9]

Taylor warns against usage of solders of low karat in soldering alloys of high platinum metal content. That type of solder has a very low fusing point and commonly contains less than 50 per cent of gold. Naturally, the behavior of the two materials, when slowly cooled, is very different. Aside from the ease with which the soldering operation can be performed, there seems little logic in the use of a low karat solder with the high-fusing orthodontic alloys. Attempts to justify the use of low karat solder are based upon the fact that soldering can be carried on at low temperatures without overheating the wire. It is true that the degree of heat required to melt the solder will not melt the wire but that some heat may cause a change in the properties of the wire, and these changes must be considered.

The more logical method of treatment of orthodontic materials, based upon the metallurgic changes involved in the process, is as follows: (1) The wires are softened prior to forming. (2) After formation, the wires are subjected to a secondary softening treatment, to minimize the effects of the forming operation. (3) The wires are joined by means of high fusing solders which may be hardened by the same general methods as the wires. (4) The completed appliance is exposed to a hardening treatment best suited to the alloys used.[5]

THE ORTHODONTIC FORCE: ITS INTENSITY AND APPLICATION

Some attempts have been made in the past to measure the intensity of forces that arch wires, finger springs, and rubber bands may develop. Still, this phase of orthodontics seems to be sadly neglected and unsettled. Korkhaus relates that Körbitz was perhaps one of the first investigators who measured, with a spring scale, the elasticity of arch wires in various expanded conditions. His experiments showed that a five mm. expansion of the arch wire exerted a pressure as high as 160 to 220 gm. and a ten mm. expansion as high as 245 to 335 gm. The results of Schlampp's recent investigations verify the findings of Körbitz and point to the fact that much smaller forces may be used successfully in modern orthodontics. Besides, Ketchams has shown by means of radiograms that excessive forces cause root resorption.

Korkhaus also refers to the two investigators, Irish and Bendias. Irish constructed an apparatus for measuring the forces of arch wires and finger springs, and Bendias' Regumeter may be used to measure the forces in the mouth. Korkhaus further states that the exact knowledge of the intensity of forces at the beginning of treatment and after activation is essential and cannot be ignored. In every case, knowledge of the actual force on the tooth, with consideration for the age and physical condition of the patient, should be the goal of the future.

In connection with the discussion of this phase of orthodontics, Korkhaus cites also the four biologic degrees of force which were enumerated by

Schwarz, and which should be kept in mind constantly when the intensity of orthodontic force is considered.[1]

Nowack stated that the modern orthodontic appliance should be of such character as to maintain the biologic optimum which, according to his explanation, is about 20 to 25 gm. per square cm. of root surface under pressure. Experiments indicate that excessive forces are more injurious than beneficial to the orthodontic tooth movement.[10]

To arouse a greater interest in the application of pressure in orthodontics, Irish urges more care in treatment. "We should always have in mind the histologic and physiologic changes in the tissue, when force is applied." We are dealing with microscopic structures. Inanimate structures can be shaped almost as desired, but not so with animals and the human body. Nature deals in transitions rather than straight lines. Therefore, we must be conscious not only of application but also of construction.[11]

Wilson states that the lack of force control may cause a thickening of the periodontal membrane, a broken-down alveolar process, resorbed tooth apices, and even pulp devitalization. He advocates an appliance capable of continuous pressure, as is characteristic of the Angle's pin and tube appliance. He adds that, according to Angle, it is possible to move teeth at a rate of speed equal to that at which they naturally erupt and still remain within the bounds of physiologic treatment. However, such a statement implies that tooth movement is continuous in one direction, which result is impossible because the force of the mechanism used may be vacillating, intermittent, or uncontrollable.[12]

Bertram is much concerned with many orthodontic procedures which are not clearly understood. The phase of orthodontics dealing with measuring forces falls under that phase. He raises the question: "Is all the practical work on patients worthless? Are we going to establish a scientific planning or continue, to do something, to put anchorage bands on so that at the next sitting we may put on the arch wire, as they will be needed anyway?" Bertram advocates practical orthodontic experimentation in order to obtain a more delicately controllable appliance which will exert a continuous pressure.[13]

MEASURING FORCES OF ARCH WIRE, FINGER SPRINGS, AND RUBBER BANDS

Attempts have been made by a number of investigators to measure orthodontic forces on models, as well as in the mouth, and some interesting conclusions were the result of these investigations. Walter experimented with arch wires and finger springs of both noble and base metals. He determined first the physical properties of the materials. Then, each material was manipulated under eight different conditions to avoid errors, and each state of manipulation was repeated three times. He concluded that every cold working of the material changes the strength, expansion, and elasticity, and that arch wire of base metals is not reliable and can be used only as a substitute. The same is true of finger springs and lingual arch wires made of base metal because they lose in elasticity with each soldering.[14]

Robinson experimented as early as 1911 with arch wires of a 20 gauge in order to make the orthodontic forces more delicate. Yet he remarks: "One of the foremost orthodontists recommended the use of a 14 gauge iridio-platinum

arch wire to secure the proper degree of expansion." However, he advises caution when small wires are used, to prevent the exertion of force at a point where it is not wanted. "The smaller the gauge and the longer the wire, the greater the danger in using it. The greater the number of bends and modifications in a wire, the greater is the difficulty in using it."[15]

Borschke was among the early investigators who suggested the construction of an apparatus for measuring orthodontic forces. "Terms such as strong and weak forces, so often mentioned in dental literature, have no foundation for the comparison of forces because the forces are not known in terms of specific figures. A strong force may as well exceed the force of 5 kg., which Herber advocates is strong enough to expand the arch. It is evident that a force of 5,000 gm. is much too great for such delicate work."

One of the ways to measure spring and arch wire is by clamping one end of the wire to a 10 cm. square board. A diagram is placed upon the board under the wire, and the results of displacement of the wire by weights are recorded by means of carbon paper upon the diagram. Weights are also used to determine the force of expansion of rubber bands.[16]

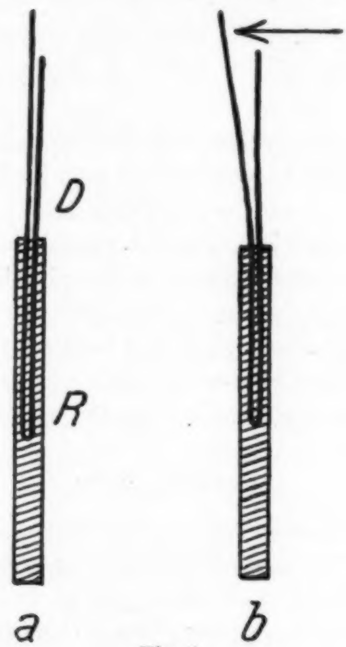


Fig. 1.

A small instrument for measuring forces in the mouth, constructed by Borschke, is explained by Schwarz (Fig. 1). This instrument is made of Wipla wire clamped in a small tube. One end of the wire is longer. A force of exactly 20 gm. will deviate the longer end 2 mm. from the shorter end. When measuring the force of the finger spring in the mouth, the activated finger spring is brought back to its former position by placing the longer end of the measuring instrument between the finger spring and the tooth. If the distance between the shorter and the longer end of the instrument, as shown in Fig. 1 *b*, is 2 mm. when the finger spring is brought to its preactivated position, then the pressure of the finger spring does not exceed 20 gm.

Bendias constructed the "Regumeter," an apparatus for measuring the orthodontic forces on a model, as well as in the mouth. Measurement is accomplished by placing a specified part of the instrument between the wire or ligature and the tooth. The inserted part is connected to the body of the apparatus, upon which a scale of pressure is recorded. The instrument may be used to determine the force of pressure, as well as the force of pull.[17]

Bertram constructed an apparatus to measure the forces of rubber bands. He measured a variety of rubber bands and concluded that the intermaxillary forces function within a 20 to 40 mm. degree of expansion and that the forces vary between 60 and 300 gm. most of the time. He emphasized that the distance between the intermaxillary hooks and the size of the rubber bands is of great importance, especially when considering the number and the type of the weight-carrying teeth. He also called attention to the fact that the actual force of the rubber bands in Class II is less in the mouth because the mandible of the patient always gives somewhat.[18]

Nowack investigated extensively the finger springs and their principal shapes and drew a number of conclusions. His work has established the fact that almost any desired force up to approximately 700 gm. is exerted by means of a 0.5 mm. finger spring under a tension which displaces the end only 1 mm.[19]

In his discussion of finger springs, Bertram is of the opinion that the modern appliance consisting of the lingual and high labial arch wire with its fine finger springs exerts a more continuous and a more delicate force than appliances formerly used and is a great accomplishment in the field of orthodontics. However, we cannot truthfully maintain that the pressure of a finger spring is continuous. The spring is adjusted by a pressure of, let us say arbitrarily, 1 to x gm., depending upon the length of the finger spring. As the teeth move, there is a gradual loss in the pressure of the spring until the point of minimum pressure is reached at the end of the four- or five-week period.[13]

BIOLOGIC FACTS

Schwarz explained in one of his articles that the orthodontic forces should be continuous and mild. In connection with this type of force, the most important biologic fact is that the resorption of alveolar bone takes place in the side of the applied pressure and that new bone is formed on the other side. Schwarz demonstrated this phenomenon as follows: Using Mershon's type of lingual arch wire with finger springs, he experimented with a young dog. He employed a loop type of spring of 0.35 mm. gauge so activated that he obtained a force of about 20 gm. at all points of initial application. All the teeth moved with this initial force of 20 gm. and produced the ideal biologic reaction in the peridontium. On the side where pressure was applied there was an equal resorption of the alveolar bone and on the opposite side there was an equal deposition of bone. The root moved through the bone with no apparent injury because the surface of the root is much harder to resorb than the alveolar bone. This biologic control of both hard substances, bone on one side and cementum on the other, accounts for the existence of orthodontics.

Another important factor that must be taken into consideration is the relative immunity of tooth surface against resorption. If the pressure is too strong, it will cause the death of the peridontium and root resorption. In direction of forces it was found that root resorption was always found at areas where the pressure was the highest. Resorption first took place after one week of continuous pressure. Age of the alveolar bone is very important. Young and especially uncalcified bone is much harder to resorb than the old one. Therefore, pressure of the tooth toward newly formed bone may cause root resorption. Exposed dentine was much less subject to resorption than the uninjured layer of cementum. The older the person, the easier will be the root resorption. Many younger individuals may be more subject to root resorption than older individuals. Constitution changes with the species; for example, monkeys are more subject to root resorption than are dogs.

The new bone formation is especially important in relation to intermittent force. This new bone formed soon after cessation of pressure is more resistant when new pressure is applied than the surrounding old bone, and root resorption may occur.

When too strong forces are applied, there is a strangulation of the peridontium as a result, and the surrounding bone becomes necrotic. These necrotic areas must be resorbed and the process is very violent and causes resorption of the root surface itself.

Another condition of root resorption may be caused by a prolonged locking of teeth, which is usually the result of an internal cause. Such locking should be regarded as a warning to discontinue orthodontic treatment. Intermittent locking of the teeth often occurs and sometimes lasts for months. Frequently, the teeth may be pushed back into their original position when the orthodontic force and the chewing force work against each other. The teeth under such jiggling condition lock to a high degree and are subject to a severe root resorption.

When confronted with the problem of why a pressure of 60 gm. is too great for orthodontic movement, Schwarz explained that forces of mastication are intermittent and the compression of circulatory periodontium remains intact, whereas the continuous pressure of orthodontic forces causes a strangulation of the periodontal tissue. The first phenomenon in resorption is the movement of the osteoclasts to the site of activity. They are capable of growing, breathing, and functioning. However, if circulation ceases, the activities of osteoclasts also cease, and the tissue becomes necrotic.

"To avoid necrotic areas and the consequent danger of root resorption when working with weak and continuous forces, the force should be biologically favorable. The capillary blood pressure in human beings is 15 to 20 mm. Hg per square centimeter. Therefore, it is apprent that a pressure of 20 to 26 gm. per square centimeter exerts a pressure upon the capillary pulsation. Naturally, the type and area of the surface under pressure must be taken into consideration. We may assume roughly that the side pressure of a premolar is distributed upon a surface of about 1 square centimeter and that some of this pressure is caught by the soft and elastic structures of the periodontal tissue. The club and sandblock type of periodontal space facilitates a fairly

equal distribution of pressure on both sides of the tilting. Some of the force is lost in mastication, some due to growth of the teeth, and the loss of force is already apparent one hour after placement of the appliance. Therefore, taking into consideration a safety measure, we may use 15 to 20 gm. on teeth with one root in a tilting movement. In bodily movement we may use about three times as much."

Naturally, if we are going to use these pressure limits, the forces of the appliances must be measurable. Schwarz criticizes, therefore, the Angle arch wire with its screws and ligatures which act upon the arch itself. In his opinion the same is true of all other types of appliances which function by means of screws. Such types of appliances can hardly be measured. However, we can measure the expansion forces set free by the Mershon-Lourie appliances in their present highly developed form, namely, the expansion forces at the free end of the principal arch and auxiliary springs in all their various forms.

The forces of the rubber rings in general use are also measurable. On the other hand, expansion of silk or wool and other such forces cannot be measured easily. Such forces are generally much too strong and for that reason, from the biologic standpoint, should be used only for short isolated actions, as in separating teeth.[20]

Schwarz also enumerated Breitner's findings on tissue changes when intermaxillary elastic, as well as jumping the bite-appliances, is used. The mandibular joint is displaced, and the condyle and mandibular angle are changed. Even the strong anchorage teeth proved to be weak in the alveolar process in the direction of the elastic. An isolated therapeutic action on the mandible by means of intraoral appliances, without shifting the rows of teeth in the alveolar process, seems to be quite impossible. However, the more gentle the intermaxillary forces and the more stable the anchorage are, the smaller the undesired shifting of the rows of teeth. In jumping the bite with inclined planes, extensive injuries were inflicted to the anchor teeth.[21]

Stuteville experimented with orthodontic forces and revealed the changes that occur in the teeth and supporting tissue when orthodontic forces are applied. He commented that the much feared injuries attributed to orthodontic appliances are more theoretical than real, and advanced some original conclusions. "We know that a necrotic area of the periodontal membrane will heal, that a resorbed area of the tooth will be repaired by secondary cementum, and that an irritated gum will heal. However, the bounds of safety can be overstepped. To prevent this, orthodontic knowledge and judgment must be used. The successful orthodontist recognizes by intelligent observation certain clinical signs which indicate that he is about to overtax the healing tolerance of Nature. Best results are procured by analyzing the forces used and allowing the supporting tissues sufficient time to react to the forces before readjusting the appliance. From the material presented, it is evident that the rapid movement of the teeth with auxiliary springs which are active through a space greater than the width of the periodontal membrane and with teeth in occlusion causes multiple root resorption. These areas of re-

sorption will disappear, provided sufficient time elapses between adjustments to allow the supporting tissues to return to normal. More rigid appliances can produce the same movement with as frequent instances of resorption. It is evident that the expanse of space through which the force is active, and not the degree of orthodontic force used, is the important factor.''[22]

THE PROPERTIES OF THE PERIODONTAL MEMBRANE

Familiar with the accumulated information of the preceding bibliographical content, the orthodontist has to bridge one more gap before he has an adequate knowledge of the elements involved in orthodontic forces.

The properties of the periodontal membrane are of extreme importance in the application of orthodontic forces. The answer to the question, "What happens to the periodontal membrane when the tooth is under pressure?" should lead to the explanation of the magnitude of orthodontic forces that the orthodontist may safely use.

At the present time we have two theories on the periodontal membrane. One theory states that the periodontal membrane is elastic, of a suspensory type; the other theory states that the periodontal membrane is incompressible.

Synge investigated the elastic cord theory of the periodontal membrance as employed by Schwarz. The forces of retention in the membrane are attributed to a large number of elastic cords or fibers acting independently. "Visualize a simple model constructed of a thin sheet of wood shaped like a tooth and anchored by an elastic cord to a fixed piece of wood, which represents the bone. This model appears satisfactory until we ask: 'What occupies the space between the elastic cords?' However, in the actual membrane these spaces are not occupied by air as in the model because the fibers are very close together. Gysi states that the membrane must be regarded incompressible[23] because when the application of an occlusal force to a tooth causes a displacement of the tooth and forces the root to approach the bone at the same place, the fibers become shorter, their volume remains unaltered and they, therefore, must bulge at the sides. If we could assume that the fibers separate and the intervening spaces are filled with air, this bulging would not be important but when the fibers are so close together the bulging of one fiber distorts the shape of its neighbor, and it is quite incorrect to believe that the fibers can function as independent elastic cords.''[24]

Synge computed mathematically the behavior of a model in which the bone and the tooth are represented by a rigid body, such as hard wood, and the periodontal membrane by a layer of an incompressible elastic substance, such as rubber. For the sake of mathematical treatment, he made simplified assumptions with respect to the properties of the periodontal membrane and with respect to the shape of the roots of the teeth. Among others, the following results were obtained by Synge's study:

1. The displacement of a tooth is very small and varies with the cube of the thickness of the periodontal membrane. This result supports the hypothesis that the periodontal membrane behaves like an incompressible body; this hypothesis also explains a rapid increase in looseness with increase in thickness of the membrane. The hypothesis of Schwarz stating that the

membrane is elastic and compressible would have the consequence that the displacement of the tooth is directly proportional to the thickness of the membrane, hence, no matter how wide it becomes, it would always suffer the same fractional extension and compression at the margin.

2. Formulae indicating the numerical value of local pressure in the membrane as a function of the applied force and independent of the rigidity and of the thickness of the membrane have been deduced by the author.

On every longitudinal section there are two points where the pressure is at a maximum, and two others where it is at a minimum. The numerical value of these pressures in the case of a force acting in a direction perpendicular to the cutting edge of the tooth can be obtained from the following formula, if the plane of the section is parallel to the force:

$$P_1 = P\ 12.25\ f$$
$$P_2 = P\ 11.78\ f$$

In this formula the unit of pressure is one gram per cm.^{2} and the unit of force one gram. *P* stands for atmospheric pressure. *F* for force. Fig. 2 illustrates the position of the four points with respect to two generators of the cone situated in a plane parallel to the force. The two maxima occur at M_1 and M_3; the two minima occur at M_2 and M_4.

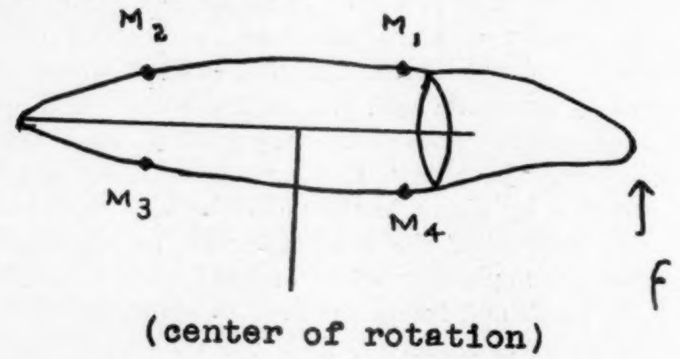


Fig. 2.

The pressure increases between the gingival crevice and M_1. A maximum is reached at M_1. Then, the pressure decreases and attains a minimum at M_2. From here on the pressure increases around the apex and reaches the second maximum at M_3. From here on it decreases until the second minimum at M_4, and increases again toward the gingival crest. If, for instance, the force applied at the cutting edge was 20 gm. (similar values have been used by Schwarz), the pressures at the four points would be the following with respect to atmospheric pressure:[25]

M_1 – 250 gm. cm.^{2}
M_2 – 236 gm. cm.^{2}
M_3 – 236 gm. cm.^{2}
M_4 – 250 gm. cm.^{2}

It is noticeable that these pressures are incompatible with the postulate used by Schwarz. According to Schwarz, loads up to 17 gm. were uninjurious, but a load of 67 gm. produces necrosis of the membrane.

Experiment No. 1

RUBBER BANDS AND THE FORCES THEY DEVELOP

Rubber bands which are used by the orthodontist are made from caoutchouc, a constituent of a milky juice called latex, which is obtainable from certain types of trees that grow in the jungles of Brazil *(Encyclopedia Britannica).*

The two most important forms of rubber are sheet and crepe. Sheet is dark brown in color, because it is dried in smoke, while crepe is a straw color and is dried in the air.

Rubber bands which are used by the orthodontist are either of crepe or sheet rubber. In the experiment both types were used. The dark brown Angle's bands (S. S. White Company, Chicago, Ill.) are probably of sheet rubber, and the straw colored Hodgman's bands (Hodgman Company, Chicago, Ill.) of the crepe type of rubber. Sizes of approximately 3, 7, and 10 mm. diameter were selected for the experiment.

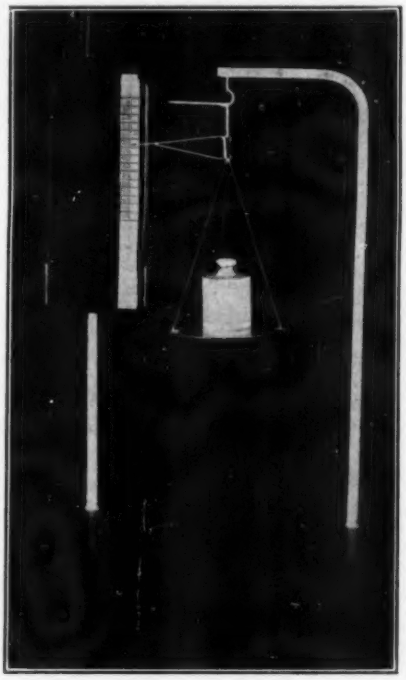


Fig. 3.

Ten of each type of rubber bands were placed into water at room temperature. All of the bands floated after 24 hours except five of the ten 3 mm. Angle's bands, which were found submerged. The experiment was repeated, and the rubber bands were left in water at room temperature for one week. At the end of this period all of the Hodgman's bands were found floating. Six of the thirteen Angle's 10 mm. bands and nine of the ten Angle's 3 mm. bands were found submerged. In the experiment later it will be shown that soaked bands lose in tension.

Fig. 3 shows the apparatus used in measuring the tension of rubber bands. The apparatus was of the type suggested by Bertram.[18] The weight of the scale was 5 gm.

Fig. 4 shows Angle's 3, 7, and 10 mm. rubber bands. Five different rubber bands were used for the 10 mm., three for 7 mm., and three for 3 mm. The curve represents the average of each size and the shaded part shows the limits of the absolute error. The black dots are the individual measurements. On the ordinate the per cent elongation is marked and on the abscissa the applied forces in gm.

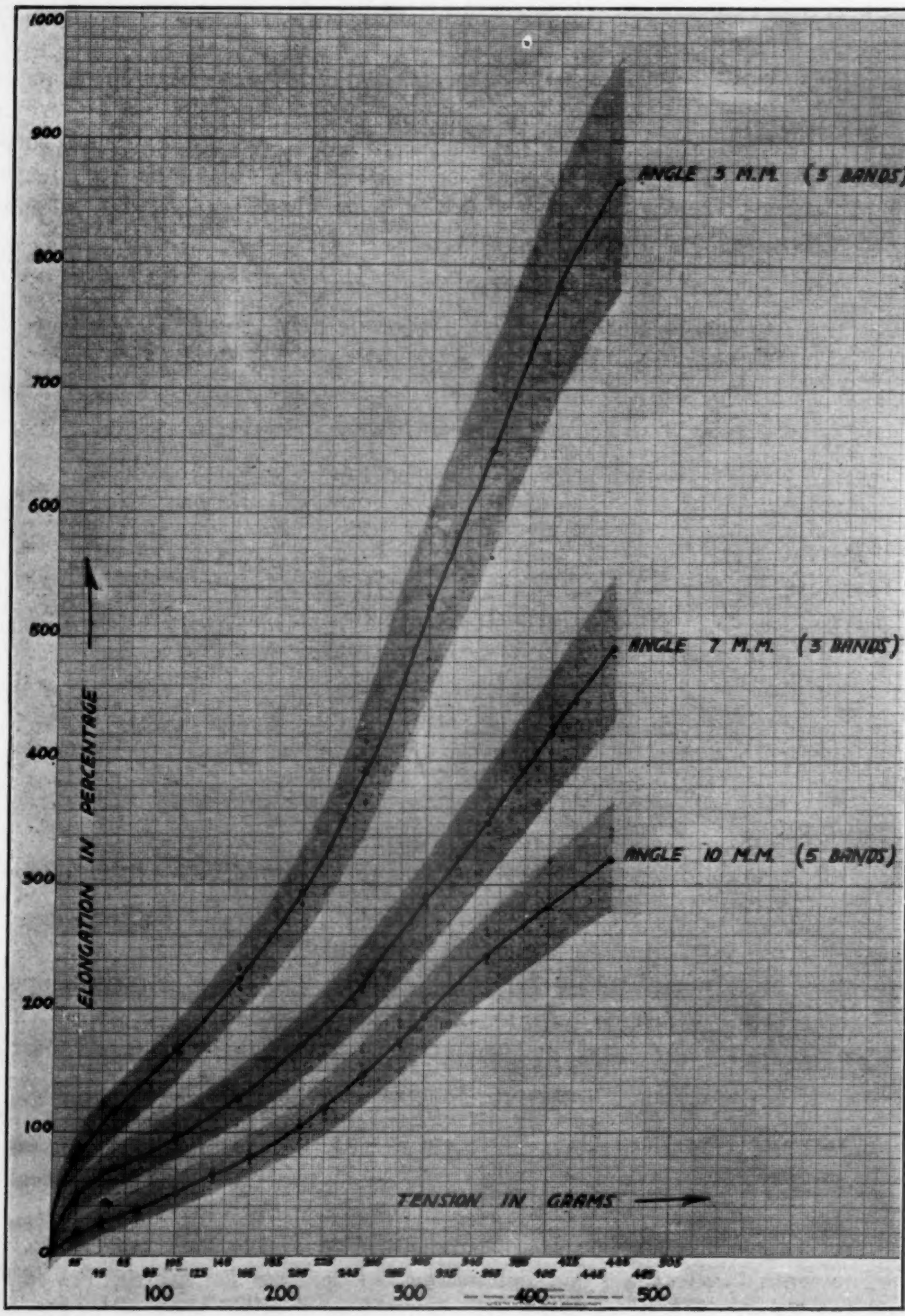


Fig. 4.

Let us suppose that a 10 mm. Angle's rubber band is stretched 30 mm.; 30 mm. is 200 per cent, which when traced upon the graph shows the applied forces to be 311 gm.

Assuming that we made an error of 1 mm. in measuring and that the error of the applied forces is negligible, we trace the absolute error on the graph in the following manner. From the point 200 per cent on the average curve we draw a line straight down to the limit of the absolute error and another perpendicular to the same point to meet the average curve. In a similar way we draw the lines above the average curve and find that 311 gm. lie between the absolute 281 gm. and absolute 355 gm.

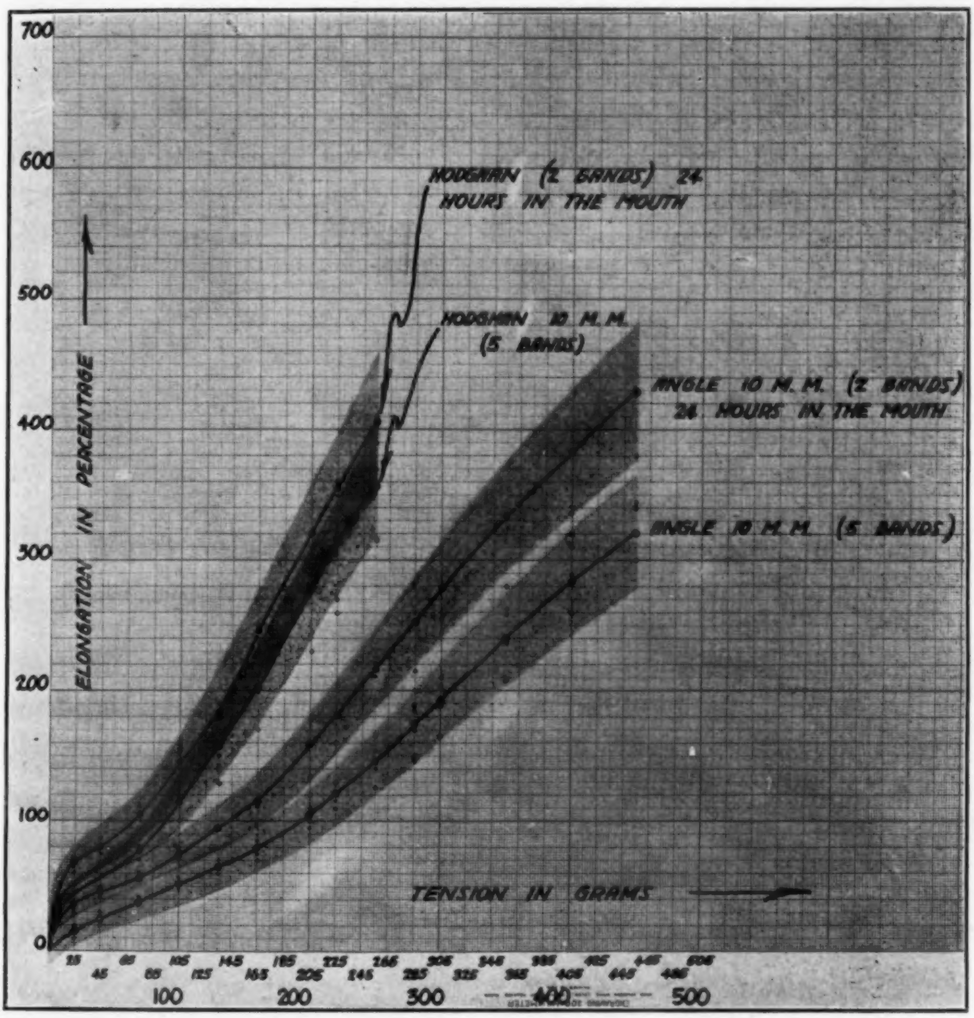


Fig. 5.

The average is 281 plus 355 (636) divided by 2 = 318

318 plus 37 = 355

318 minus 37 = 281

Per cent of error = 3700 ÷ 318 = 11.6 per cent and 3.11 × 11.6 = 36. The tension of the 10 mm. Angle's rubber band at 200 per cent expansion is, therefore, 311 ± 36 gm.

Fig. 5 shows the average curve of five mm. Angle's rubber bands and the average of two of the same type which have been in the mouth for twenty-four hours. In tracing for 200 per cent expansion we find that when the bands are in the mouth for twenty-four hours, the tension is not 311 but 239 gm., a loss of 72 gm. of tension.

The average curves representing five different Hodgman's 10 mm. rubber bands and two of the same type after being twenty-four hours in the mouth show that there is only 165 gm. tension at 200 per cent stretching and a loss of 22 gm. after being twenty-four hours in the mouth. To get the exact tension the absolute error must be calculated in all these cases.

Fig. 6 shows the average curve of three 3 mm. Angle's rubber bands. Some of the rubber bands were placed into water at room temperature and many of them became submerged after twenty-four hours. The lower curve represents the dry bands, while the upper curve represents the soaked bands.

At 500 per cent stretching the dry rubber band has a tension of 295 gm. and the soaked one 283 gm. There is a loss of 12 gm. of tension when the rubber band is soaked. Here, too, the absolute error must be considered.

EXPLANATION OF CALCULATION

To find the percentage elongation:

Let l represent the original length
Let m represent the measured length

$$\% = \frac{m - l}{l} \times 100 = 100 \left(\frac{m}{l} - 1 \right)$$

Example: $l = 10$, $m = 14$

$$100 \left(\frac{14}{10} - 1 \right) = 14 \div 10 = 1.4$$
$$1.4 - 1 = .4$$
$$.4 \times 100 = 40\%$$

To find the absolute error:

Let l_1 = original length of the rubber band
Let l_2 = stretched length of the rubber band
Let p = percentage elongation
Let δ = absolute error of p
$\delta l_1 = \delta l_2$ = absolute error of length measurement
We assume that the error in measurement is within 1 mm.
We assume that the error of applied forces is negligible.
$l_1 = 10$ mm.

$$p = 100 \left(\frac{l_2 - l_1}{l_1} \right)$$

$$\delta p = 100 \frac{\delta l_2}{l_1} \text{ plus } \frac{l_2 \, \delta l_1}{(l_1)^2}$$ partial differentiation with respect to l_1 and l_2

Let $\delta l_2 = \delta l_1 = 1$
$l_1 = 10$

$$l_2 = l_1 \left(1 + \frac{p}{100} \right) = 10 \left(1 + \right) \frac{p}{100}$$

$$\delta p = 20 + \frac{p}{10}$$

Example: $p = 11.6\%$
$\delta p = 21.16\%$

The absolute error 21.16 per cent is then marked on each side of the average curve at the point of the percentage elongation.

Experiment No. 2

FORCES DEVELOPED BY THE ARCH WIRES

Fig. 7 shows the apparatus used in the experiment. It is of the same type as suggested by Irish.[11] However, a number of changes were made in its construction to make this type of measurements possible.

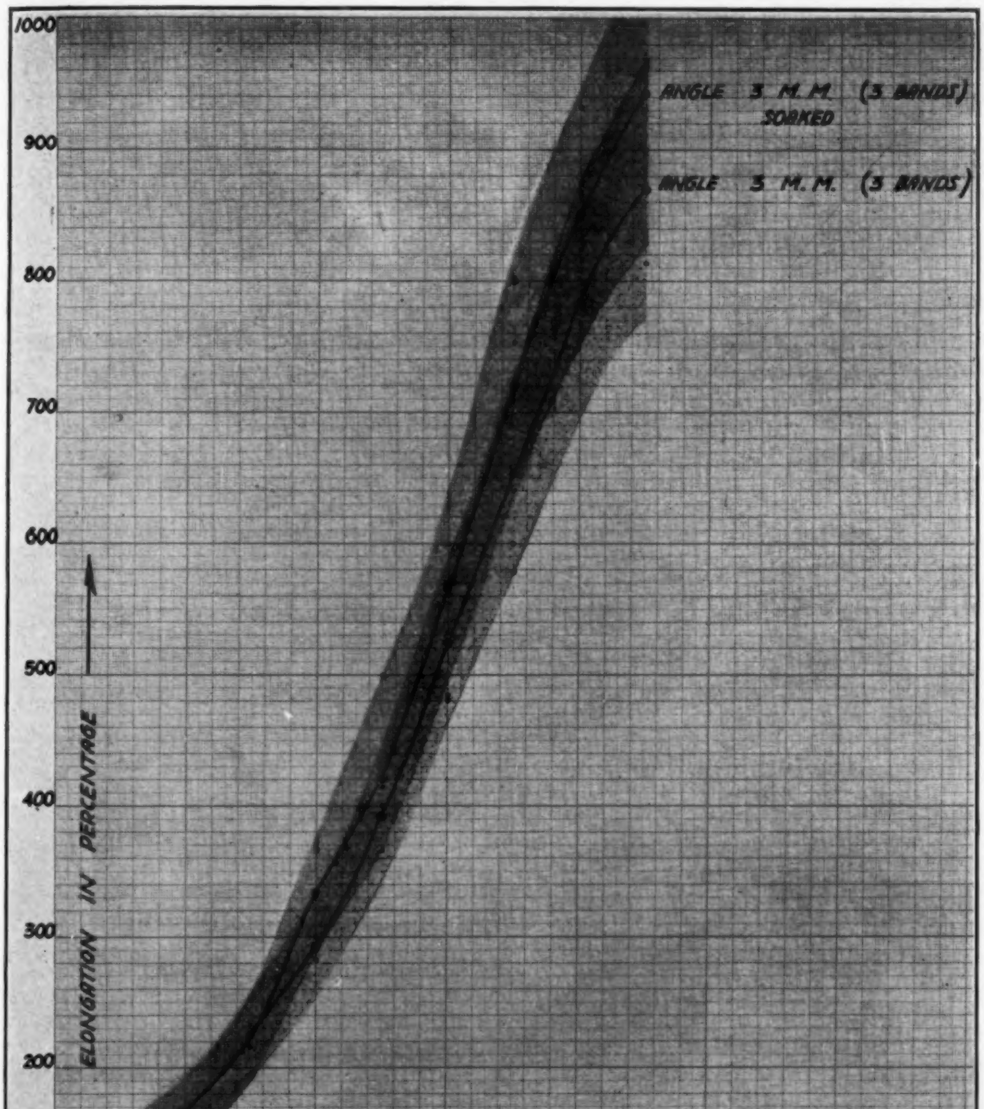


Fig. 6.

An orthodontic band with a closed tubing and a stop lug was cemented on the right first molar, and the same type of band with a fork was cemented on the left first molar. The fork was made of 20 gauge wire and soldered to the band horizontally in such a manner that its ends, placed above each other, could be used to make the measurements more accurate when the arch wire was brought into their alignment. A band with an open tubing was cemented upon each central incisor. An arch wire of known gauge, length, material, and the desired bending was placed into position and ligated at the distal point of the open tubing of each of the central incisors with a ligation device.

The force indicator was then brought to the point of force application, so that the force acted perpendicularly upon the buccal surface of the tooth. Fig. 7 shows also an arch wire in position, ligated, and under tension.

Materials used for arch wires were gold-platinum (S. S. White Co., Chicago), Monel spring wire (Steel Sales Corp., Chicago), and stainless steel (Chicago Steel Service Co., Chicago). The length of each wire was 100 mm. and the gauge #20 (0.032). Physical and chemical properties of the material were recorded as given by the manufacturer.

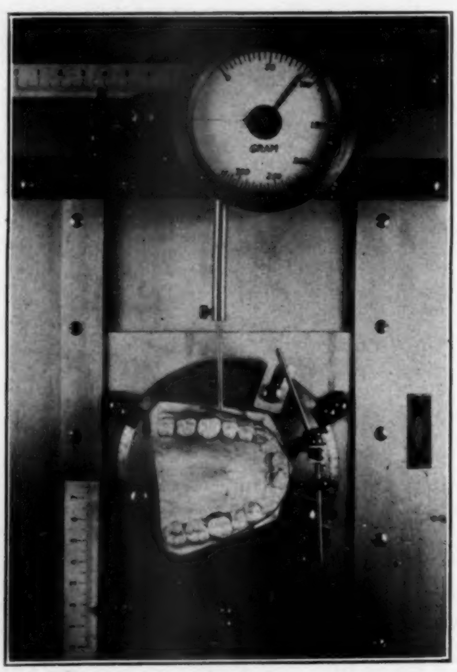


Fig. 7.

Gold-platinum composition and physical properties:

Gold ----------------	.636 slightly more than 63 per cent
Platinum ------------	.105 slightly more than 10 per cent
Contains no pallidium	

Ultimate tensile strength when air cooled	—143,600 lbs. per sq. in.
Proportional limit when air cooled	—116,000 lbs. per sq. in.
Elongation when air cooled	— 2.1 per cent

Fusion temperature of this type of wire is 1733° F. (945° C.)
Solder used in connection with lingual appliances was of approximately 13 karat, 600 fine, its fusing temperature being about 1400° F. (760° C.).

Monel spring wire:

Nickel	68 per cent
Copper	29 per cent
Manganese	1.5 per cent
Iron	1 per cent
Other elements	0.5 per cent
Ultimate tensile strength	161,590 lbs. per sq. inch
Proportional limit about	120,000 lbs. per sq. inch
Elongation	15 per cent
Brinell hardness	225
Melting point	2460° F. (1371° C.)

Stainless steel "Enduro" 18-8:

Carbon	.08 to .20 per cent
Chromium	17.0 to 19.00 per cent
Nickel	7.0 to 9.00 per cent
Silicon	0.75 per cent
Manganese	0.60 per cent
Sulphur	0.03 per cent
Phosphorus	0.03 per cent

Average physical properties of 18-8 heat treated (annealed) bars up to 2" Rd.:

Ultimate tensile strength	85,000 lbs. per sq. inch
Proportional limit	35,000 lbs. per sq. inch
Elongation in 2"	55 per cent
Brinell hardness	156
Melting point	2560° F. (1404° C.)

The work hardening characteristics of this type of stainless steel permit considerable increase in tensile strength and raising of its proportional limit (yield point) by cold working operations. It is not uncommon to find 250,000 tensile strength, 2 per cent elongation, and 40 to 45 Rockwell "C" hardness in cold drawn 18-8 wire.

The wire was bent and expanded 2, 4, 6, 8, and 10 mm. around a fixed point. At each expansion a new wire of the same type and gauge was used, and the measurements were repeated three times. It soon became apparent that bending had a tremendous influence on the wire. Consequently, a number of curves were reproduced, which, although not always easily reproduced, gave a fairly good basis for the continuation of the experiment.

Fig. 8 shows a number of types of arch wires and curves, which show how different bendings influence the tension of a 20 gauge gold-platinum arch wire. The angular type had a tension of 42 gm. in the molar region and was therefore the lowest in tension at that particular point. The type depressed in the lateral incisor had a tension of 90 gm. in the molar region and was therefore the highest in tension.

Wires of gold-platinum, Monel, and stainless steel were then bent to a specific type and expanded 2, 4, 6, 8, and 10 mm. Measurements taken at each successive expansion show the difference in tension each type developed. The succeeding figures show on the left side the materials cold worked, and on the right, the same materials subjected to the heat treatment or soft soldering

operations. Soldering was performed in the canine region with lead solder which has a low fusing temperature.

Monel and stainless steel wire were soldered and then plunged into water at room temperature to ascertain what influence, if any, such operations impart on the wire. Care was taken during soldering not to overheat the wire, as overheating this type of wire tends to make the metal soft and brittle at the point of soldering.

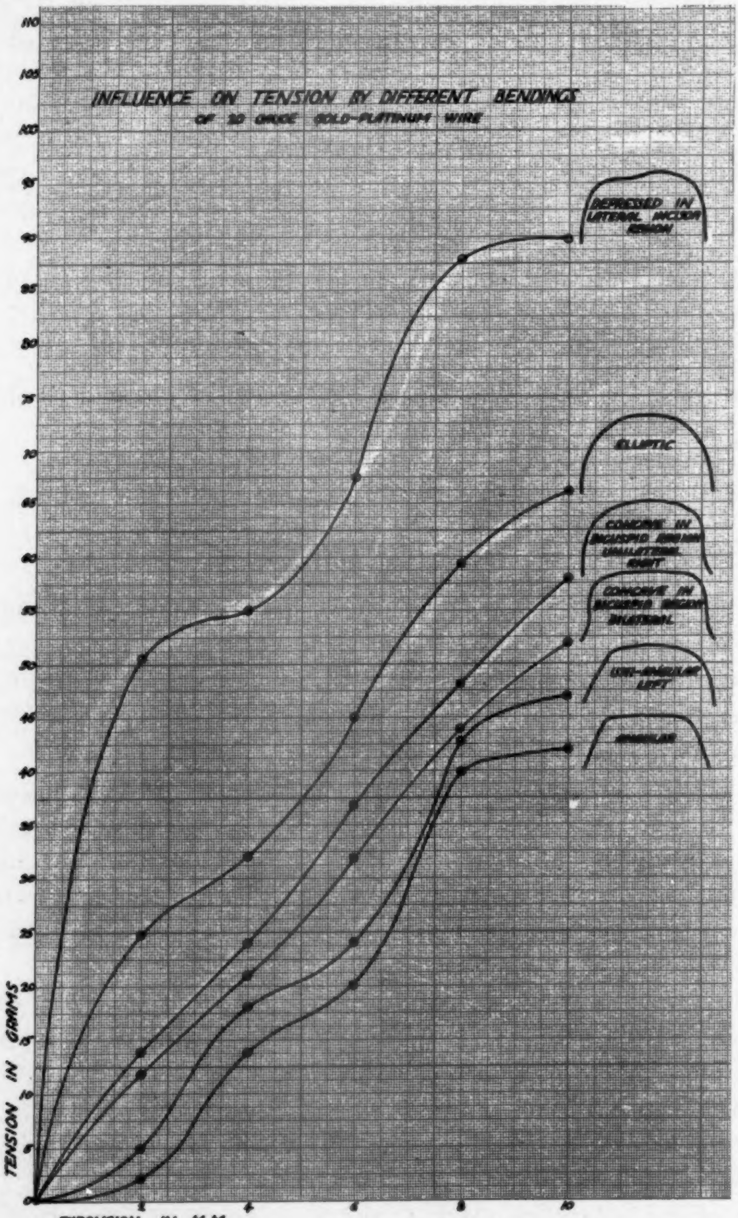


Fig. 8.

Gold-platinum was heat treated according to the manufacturer's instructions. The specimen was heated in an electric furnace to a temperature of 1300° F. (704° C.) and plunged into water at room temperature, then re-

heated to 840° F. (448° C.) and cooled to 480° F. (226° C.). The time required for the slow cooling was half an hour, and the treatment should have given the specimen its maximum of resiliency.

Fig. 9 shows the angular, uniangular left, and concave bilateral type of arch wires in the bicuspid region, and curves. When expanded 10 mm., gold-platinum had 42 gm., Monel 78 gm., and stainless steel 86 gm. of tension. In

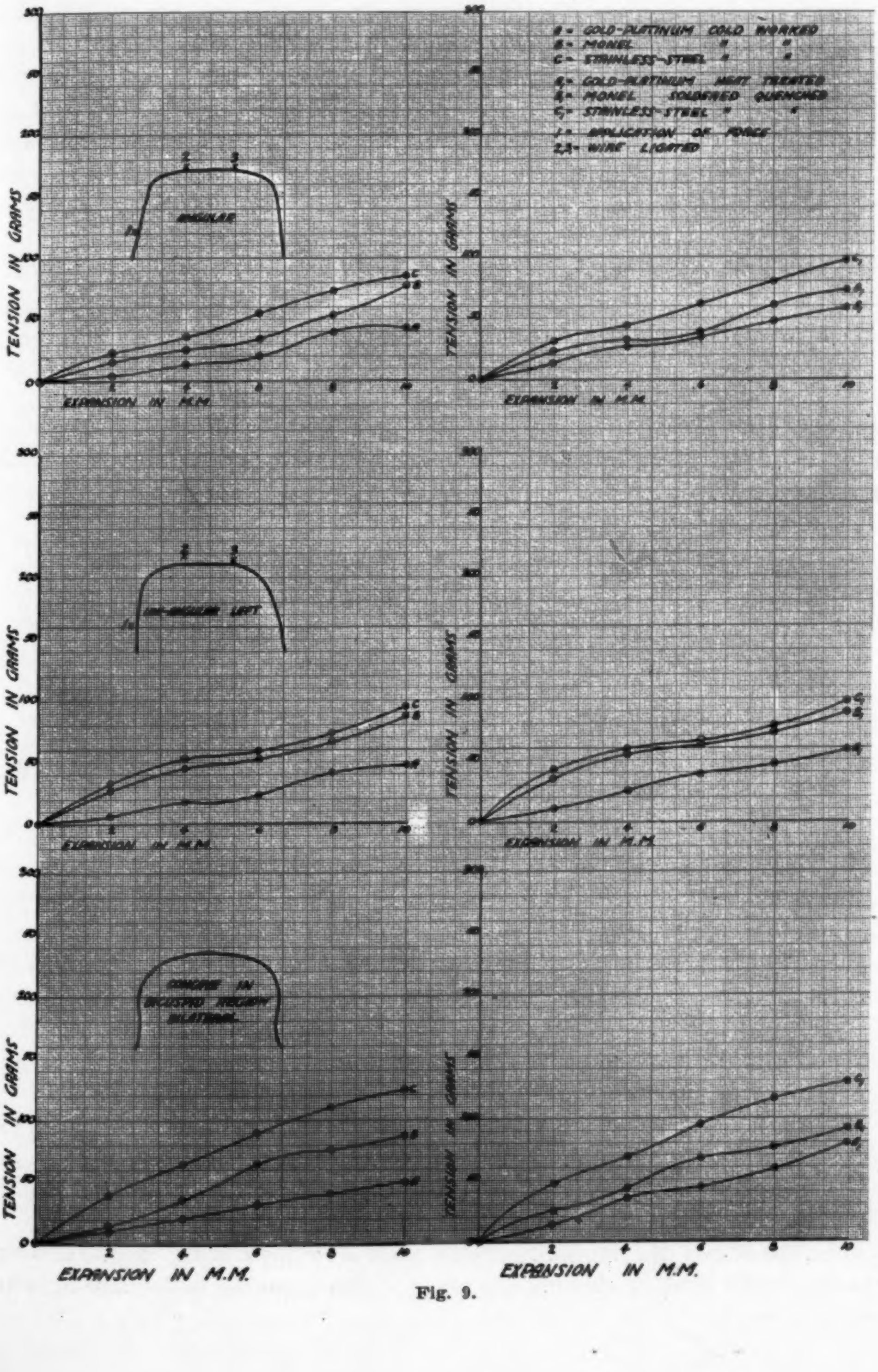


Fig. 9.

a similar way the right side curves show an increase in tension when the gold-platinum wire was heat treated and Monel and stainless steel soldered and plunged into water at room temperature.

Experiment No. 3

FORCES DEVELOPED BY THE FINGER SPRINGS

The apparatus used in this experiment was of the same type as that used in Experiment No. 2. A cast with removable teeth was clamped on the apparatus. An orthodontic band with lingual lock was attached to the left and right first molars by means of a buccal screw. The lingual (Mershon) type of appliances was constructed with finger springs acting upon the left first premolar, left lateral incisor, and left central incisor. The distance between the point of the force application of each tooth and the lingual arch wire was measured and recorded. The teeth were then removed, the force indicator brought perpendicular to the finger spring at the point of the force application, and the tension of the finger spring measured for each tooth after activation of 1, 2, and 3 mm.

The materials used were gold-platinum and stainless steel "Wipla." Gauge #19 wire was used for the lingual arch wire and gauge #23 for the finger springs. The gold-platinum wire, including the solder, was of the same variety as indicated in Experiment No. 2. The "Wipla" stainless steel wire and solder used with it were supplied by the Austenal Laboratories of Chicago, Illinois.

"Wipla" stainless steel—composition and physical properties.

Chromium	18 to 19 per cent
Nickel	8 to 9 per cent

Balance iron, with exception of fractional percentage of silicon, manganese, and carbon, the latter being less than .10 per cent.

Ultimate tensile strength	about 200,000 lbs. per sq. inch
Elastic Limit	about 180,000 lbs. per sq. inch
Elongation	not over 5 per cent
Brinell hardness	around 400.
Melting point	2500° F. (1371° C.)

The physical properties of this type of material depend on the amount of cold work performed in the drawing of the wires following an anneal, and are, therefore, closely controllable. Wires can be produced in a wide range of properties, from an annealed wire with an elastic limit of about 35,000 pounds per square inch to a full hard drawn wire up to 400,000 pounds tensile strength, in which condition the wire is very hard and has an elastic limit very near the ultimate strength. It is possible to produce wire of various degrees of hardness, and the Brinell on soft annealed wire is as low as 170.

Solder used in soldering stainless steel lingual appliances was .583 fine and, in addition to the gold indicated, contains silver, copper, nickel, and zinc. Its melting point is 1290° F. (698° C.), and its flow point is 1360° F. (737° C.).

Fig. 10 shows the model mounted upon the apparatus. Fig. 11 shows the same model with teeth removed and the finger spring under tension after being activated.

Fig. 12 shows the enlarged model with teeth in position. The lingual arch wire is also in position, and the finger spring is in unactivated relation to the first premolar, left lateral incisor, and left central incisor.

Fig. 13 shows the same model with teeth removed, and the finger spring activated and ready to be measured for tension.

Three types of finger springs were used: compound, compound recurved, and compound finger spring with wrapped attachment.

Fig. 14 shows the three types of finger springs and the curves of tension they develop. On the left are the curves developed by the heat treated gold-platinum, and on the right, the curves of the "Wipla" stainless steel type of finger springs.

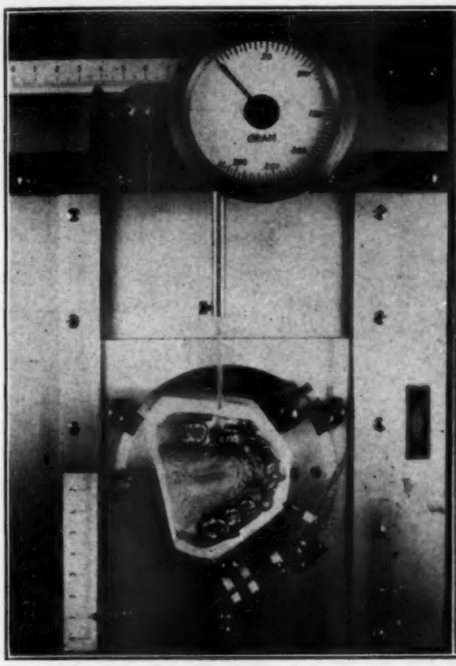


Fig. 10.

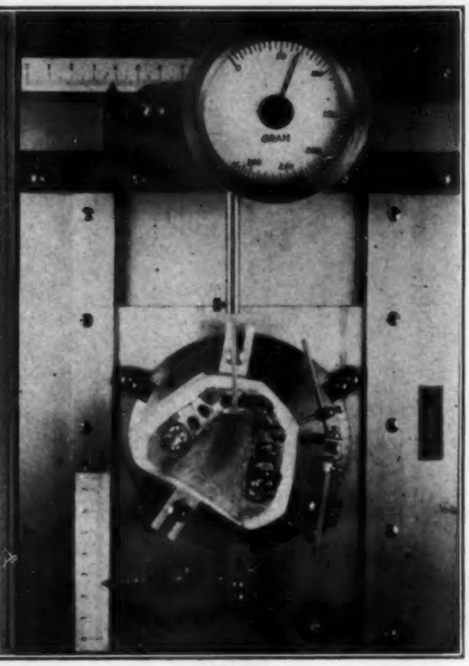


Fig. 11.

The left first premolar developed the highest tension and the left central incisor the lowest tension. This points to the established fact that the longer the arm of the finger spring, the less will be the tension toward its free end. For example, when heat treated, a compound recurved finger spring of the gold-platinum type developed, when activated 3 mm., a tension of 260 gm. in the first premolar, 80 gm. in the left lateral incisor, and 50 gm. in the left central incisor region. The curves of the heat treated gold-platinum type also indicate that compound finger springs of wrapped attachment are more constant and the lowest in tension.

Experiment No. 4

TENSION DEVELOPED BY #20 (.032) GAUGE STAINLESS STEEL WIRE OF VARIOUS DEGREES OF HARDNESS

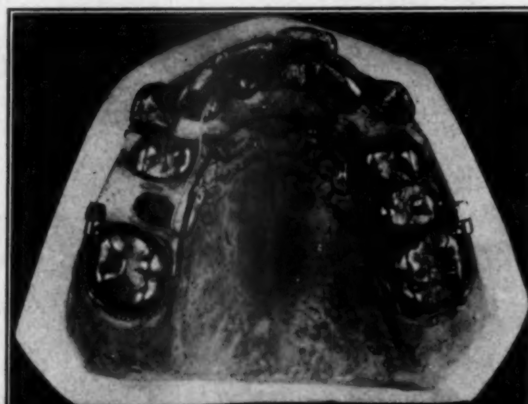
Wire for this experiment was supplied by the Chicago Steel Service Company, Chicago, Ill., and is of the same type as the stainless steel wire used in

Experiment No. 2. The specimens were of various degrees of hardness and were enumerated by the manufacturer as stainless steel of soft, and ¼, ½, ¾, and full hard.

Two pieces of 100 mm. length of each type of hardness were used and bent similarly to the shape used before in Experiment No. 2. After stretching the wire 5 mm. on each side, it was mounted upon the apparatus, ligated and the tension of each wire recorded. Three measurements were taken of each wire. The averages of each hardness were as follows:

Soft	69 gm. and 66 gm.
¼ hard	81 gm. and 80 gm.
½ hard	89 gm. and 90 gm.
¾ hard	97 gm. and 101 gm.
Full hard	114 gm. and 113 gm.

Fig. 12.



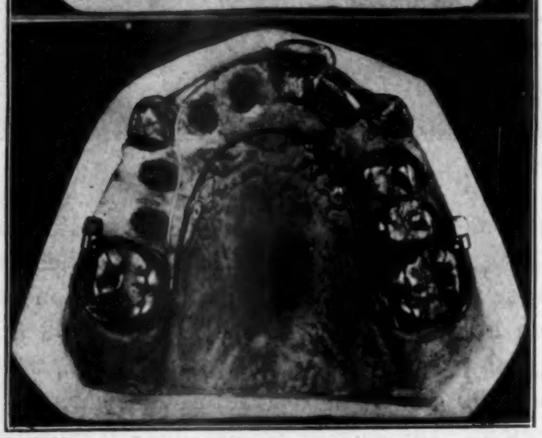


Fig. 13.

Four pieces of the above wire of the half-hardness type were then heated to 1500° F. (815° C.). Two pieces were quenched in water and two cooled in air. All four pieces displayed the same characteristic; they became soft (annealed). The same thing happened to four additional pieces of the same type of wire which were submitted to the same heat treatment but heated to 1600° F. (871° C.).

CONCLUSION

Knowledge of the intensity of forces used in orthodontic tooth movement is a timely requisite which should equip an orthodontist with a finer concept in solving his complicated problem of restoring the physiognomy of the face.

A thorough familiarity with the properties of materials an orthodontist uses, the types of appliances and the principles involved in their construction,

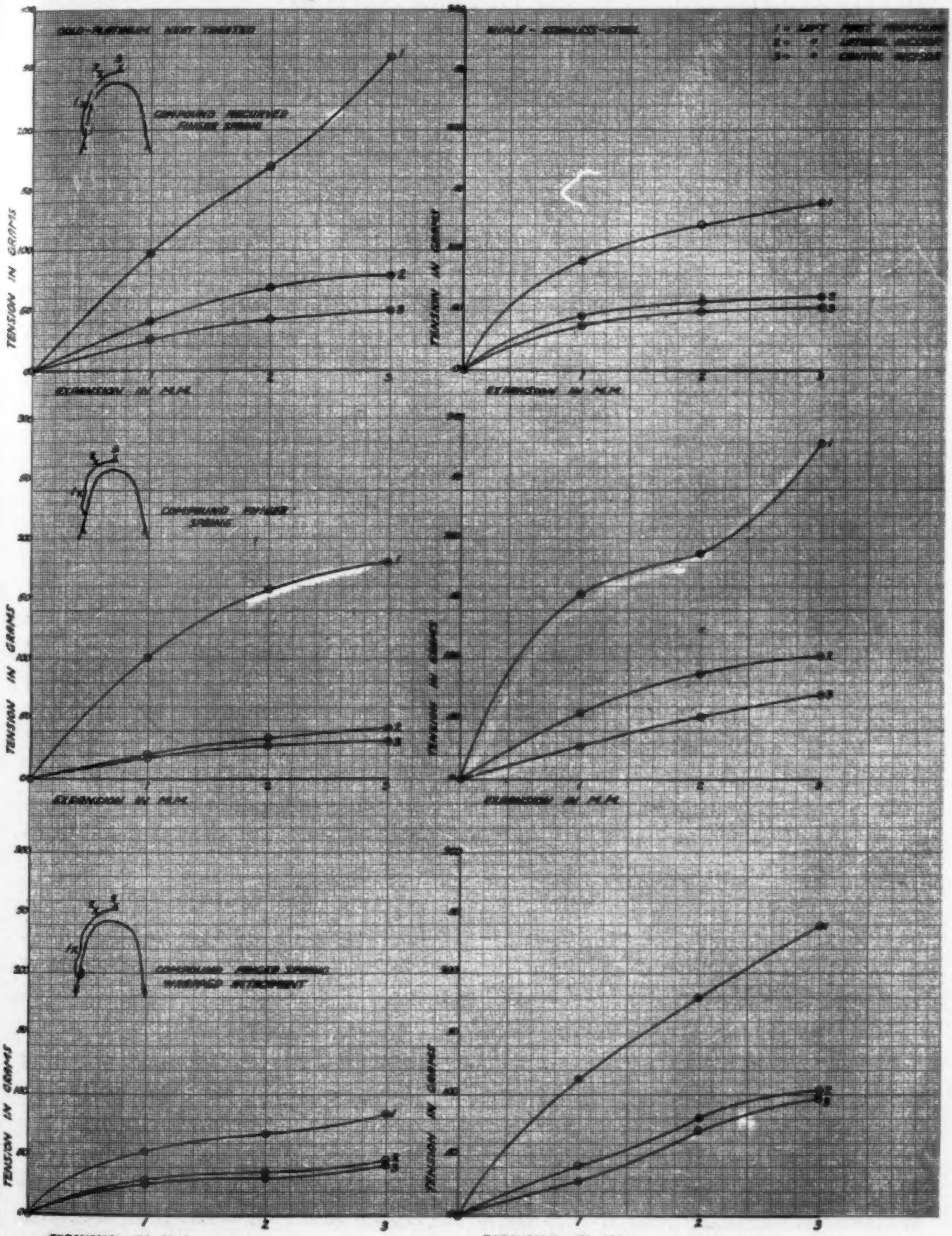


Fig. 14.

such as soldering and heat treatment, and the forces such appliances develop and exert upon the teeth, will do much to eliminate the danger of root resorption and other pathologic conditions in the periodontal tissues.

Since wrought wires are used extensively in the construction of orthodontic appliances, such wires should possess properties which will meet the requirements of the finished product. The most important requirements of wrought wires for orthodontic use, therefore, should be:

1. High proportional limit—to insure the toughness and resistance to fatigue from stress incident to mastication, and for stability against permanent deformation in bending.

2. A low modulus of elasticity—to maintain satisfactorily the pressure despite the movement of the teeth.

3. Ductility to show toughness.

4. Proper hardness to resist wear—not extreme carbide hardness which may endanger the enamel of the teeth.

5. Resiliency as opposed to rigidity in the alloys for expansion, as in arch wires and finger springs.

6. Ease and security in soldering—permitting modification of design and repair.

7. Basic resistance to oral secretions—all the way through the metal.

8. Capable of being softened for adequate adaptation, and subsequently hardened for long life.

9. Capacity for high polish.

10. Availability of the alloys for each specific type of restoration.

Wrought wires of gold-platinum meet nearly all of the above requirements, and their usage is well recommended by the leading orthodontists. The ease with which these are shaped, soldered, and their properties controlled by heat treatments makes them ideal for the construction of orthodontic appliances. However, one should demand from the manufacturer a detailed analysis of the properties of the wire, including instructions on how to heat treat the wire. Also, he should know the fine points of soldering, the melting point of both wire and solder, and the type of solder that should be used to make better soldering joints.

Besides gold-platinum, much of the material used in orthodontics is of base metal. German Silver and Monel spring wire easily corrode in the mouth, and might be overheated when soldered. These metals are gradually being replaced by stainless steel.

Stainless steel of the Chromium-Nickel type is the most corrosive resistant. This type of stainless steel gains its strength almost entirely from cold working and cannot be heat treated for hardening. The wire can be made softer by annealing, and no heat treatment or method of cooling following a heating, will do anything other than make hard wire softer. After soldering or welding, the material becomes weak at or near the joint, has a very low proportional limit, and may tend to corrode in the region in which it has been soldered. Following a soldering operation, cold working, in the sense of producing severe

deformation, is of course impracticable. There is some possibility of restoring resiliency by subjecting the area involved to vibrating alternating stresses of small magnitude.

The fact that this type of wire is obtainable in 0, ¼, ½, ¾, and full spring and hardness, in low and high tensile strength, and that it can be machined for screw, makes this type of wire adaptable for arch wires. For the lingual (Mershon) type of appliance, stainless steel is less suitable, yet finger springs may be soldered to a thin stainless steel band which is adaptable and could be welded to the arch wire by an electric welder. For retainers and such types of appliances, where the wire may be used in an annealed condition, stainless steel is very suitable.

In soldering stainless steel, care should be exercised to heat the parts just enough to flow the solder and thus retain a maximum resiliency where it is desired. According to the manufacturer, actual tests for resiliency, following heating to various temperatures, indicate that the wire can be heated to 1500° F. (815° C.) with no loss of properties. However, if this temperature is exceeded, the wires soften and lose resiliency, and at 1600° F. (871° C.) there is a marked lowering of resiliency.

The following are the melting points of silver solder:

Grade 1	1510° F. (820° C.)
Grade 2	1430° F. (775° C.)
Grade 3	1430° F. (775° C.)

The melting point of silver solders indicates that it is not safe to use them in soldering stainless steel wire, if the resiliency of the wire is to be maintained. The .583 solder, recommended by the Austenal Laboratories, has a melting point of 1290° F. (698° C.), low enough to avoid danger of overheating, and is more preferable. In connection with this explanation one can see that the soft solders of plumber's variety which have a melting point between 370° F. (190° C.) and 500° F. (260° C.), can be used on stainless steel provided one does not overheat the wire.

Much objection to stainless steel wire is due to the stiffness it develops when cold worked. This material is inherently twice as stiff as the precious wires. Precious wires of gold-platinum alloys will bend twice as far or twice as easily for any load within the proportional limit as will wires of steel alloy. This feature is especially important to an orthodontist because with the same initial pressure, a tooth can be moved twice as far with a gold-platinum spring as it can with a steel spring of the same size.

Flexibility, too, is very important. A wire of the lowest modulus of elasticity should be selected, as the higher the modulus of elasticity, the stiffer the wire. This property is of importance when stresses of mastication and stresses upon the anchorage or retaining teeth have to be considered. Such stresses are only half as great in precious metal wires as in stainless steel wire, because precious metal alloys have a modulus half as high as stainless steel.

Also, hardness of stainless steel should be controlled, as the hardness of dental alloys should be below that of the enamel of the teeth. Glass-hard carbides or hard spots in wire should be avoided, as such conditions may wear the tooth.

As determined by the experiments regarding orthodontic forces, rubber bands are of great importance to the orthodontist. For example, in Class II malocclusion, the rubber band is placed upon the intermaxillary hooks. Suppose the distance between the intermaxillary hooks is 30 mm. when the mouth is closed and 40 mm. when it is open. If a 10 mm. rubber band of the Angle variety is used, a 30 mm. expansion denotes a 200 per cent elongation and 40 mm., a 300 per cent elongation. Tension developed under these conditions fluctuates between 311 gm. and 425 gm. With Hodgman's type of rubber band of the same size, the forces fluctuate between 165 gm. and 215 gm. Making allowances for the loss of tension due to fatigue when the band is in the mouth for an extended period of time, the tension of the particular rubber band may be calculated within defined limits of experimental error. Besides the magnitude of forces of the rubber bands, the distance between the intermaxilary hooks and the number of teeth upon which the forces are to be distributed should be known.

The experiment with the arch wires leads into many directions. The magnitude of tension of the wire is influenced by the method of bending, degree of expansion (activation), heat treatment, and soldering. After an arch wire is activated, placed into the mouth and ligated, we may asume that the tension of the wire acts upon the teeth that were ligated.

The experiment with the finger spring is especially significant in showing the difference in tension due to gold-platinum and stainless steel finger springs. The forces of the gold-platinum compound finger spring of the wrapped attachment type seem to be the most delicate in comparison with other types of finger springs appearing in the experiment. The experiment also indicates the danger of too great a magnitude of tension in finger springs when overactivated.

Experiment No. 4 deals with stainless steel wire of different degrees of hardness. Arch wires show an increase in amount of tension as the hardness increases. The experiment also shows that by heating the wire above 1300° F. (815° C.) the wire becomes soft (annealed) regardless of how it is cooled. The soft and one-fourth hard stainless steel arch wires develop a tension which is closest to the tension developed by the gold-platinum arch wires.

Technical training in construction of the orthodontic appliances, as well as metallurgic knowledge of the materials one is using, should ultimately lead to the construction of orthodontic appliances which produce forces that are measurable.

The question of the magnitude of forces which may be used safely in orthodontic tooth movement needs further investigation. Both Schwarz and Synge discussed this particular question in their respective theories of the periodontal membrane and mentioned the magnitude of the forces.

Kanner is of the opinion that Schwarz seemingly has failed in his estimation of the proper range of the magnitude of the orthodontic force. "Schwarz's assumption, that undesirable changes (necrosis) would occur within periodontal membrane whenever the pressure of orthodontic force within this membrane reaches a value higher than that of the capillary blood pressure, is questionable. It is true that any tissue without blood supply will become necrotic, but lack of blood supply and lack of blood circulation within a narrow area are not the same thing. There are tissues in the body which are devoid of blood vessels and yet live.

"There also are fundamental facts which must be considered. Forces are vectorial quantities, e.g., they are defined not only by their magnitude, but also by their direction. When defining a pressure as force per unit area, the angle under which the force acts must be considered. In physics, pressure is defined by the force per unit area with the specification that the direction of the force is perpendicular to the area under consideration.

"It is quite apparent that the consequences of suppressed circulation within the periodontal membrane depend upon a number of factors which Schwarz has apparently not taken into consideration, such as the pressure distribution or the size of the region exposed to relatively high pressures. These factors depend not only upon the magnitude of the applied force but also upon its direction, upon the shape of the root surface, and upon quite a number of hitherto unexplored properties of the periodontal membrane."

In the same way, if we attempt to look to Synge for an answer as to the magnitude of orthodontic forces, we are not sure that Synge's results correspond with the clinical experiences. Kanner made the following observations.

"1. We assume that the analytic results of Synge are logical deductions from his assumptions about the properties of the periodontal membrane.

"2. We shall not question the validity of these assumptions so long as they lead to results which are compatible with clinical experience.

"3. We shall disagree about the validity of the assumptions if relevant deductions drawn from them lead to contradicting experience.

"No doubt many of Synge's results justify his assumptions. However, this discussion shall be restricted to those results which, in our opinion, are contradicted by experience.

"A. The motility of normal teeth is considerably greater than would be expected from Synge's results.

  "a. An external force applied upon a tooth, for instance, by the fingers, causes a displacement visible to the naked eye.

  "b. In cases of periodontitis teeth may undergo a noticeable axial displacement.

"B. Certain orthodontic experiences do not harmonize with some of Synge's results. Let us consider the magnitude of pressure upon the periodontal membrane due to an external force. Following Synge's calculation, a force of 20 gm., for instance, applied perpendicularly to the cutting edge of a tooth with a conical root (cone of revolution) would induce a pressure upon the periodontal membrane of up to about 250 gm. per $cm.^2$ above atmospheric pressure. The blood pressure within the capillaries of the periodontal membrane is of the order of 25 gm. per $cm.^2$ above atmospheric pressure. Hence we must deduce that a force of a few grams, say 3 gm., would induce an ischemia involving considerable area of the periodontal membrane: necrosis would follow. As a matter of fact, necrosis of the periodontal membrane due to the application of orthodontic forces has been observed, but experience shows that such is never the case if the external force is less than say 25 gm. Hence, the maximum pressure exerted upon the perio-

dontal membrane by a force of the order of 25 gm. does not surpass the order of magnitude of capillary blood pressure within the membrane; therefore, Synge's results concerning this pressure disagree with experience, and we are led to review his assumptions about the properties of the periodontal membrane. . . .

"Before doing so, we might try to make use of some of Synge's analytic results in an attempt to gain information about properties of the periodontal membrane by comparing such results with actual experience. The absence of ischemia in the case mentioned above can be accounted for only by assuming either that the amount of pressure upon the periodontal membrane is radically less than the one postulated by Synge's results, or that some mechanism prevents the pressure from acting upon the blood capillaries within the periodontal membrane. Now, it appears quite obvious to us, from mere inspection and without any calculation, that the maximum pressure due to a force of say 20 gm. would be far superior to capillary blood pressure. Hence, we must assume the presence of a protective mechanism. The assumption of the tooth's being suspended by fibers connecting it to the bone would take care of the argument: the external force is then in equilibrium with forces of stress of the suspending fibers, and relatively little strain is exerted upon the opposite side of the tooth. It appears to us that, in view of experimental facts, the assumptions underlying some of Synge's results should be modified so as to admit the following facts: (1) the membrane is anisotropic and (2) parts of the membrane are quite compressible.

"We wish to call attention to the fact that in the human body collagenous fibers, as present in the periodontal membrane where they form a peculiar arrangement, always develop in such a way as to withstand stresses. Examples of this are: We find them in parallel bundles in tendons and in the periodontal membrane. They cross at right angles in an aponeurosis. They cross at various angles within the periosteum.

"Within the periodontal membrane the fibers fail to develop prior to the eruption of the tooth. This fact suggests the assumption that masticatory forces have something to do with their development, and that the direction of the bundles is determined by the direction of stresses induced by such forces."

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FACTORS WHICH CONTROL THE TREATMENT OF THE DWARFED MANDIBLE

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AMONG those who apply for help in the field of dentofacial orthopedics, the patient with the dwarfed mandible has the greater appeal to me. This aberration of growth is usually accompanied by other anomalies, each of which contributes to, or is a part of the anatomical and functional malarrangement. The frequency with which it occurs places it among the chief problems of orthodontics, and more than justifies any study which may aid in clarifying predisposing and exciting causes, and form the basis for rational treatment.

For the past ten years or more, I have recorded the progress of cases in an effort to determine the actual results of treatment. This procedure is absolutely necessary if the efficacy of a treatment program is to be determined. Upon two previous occasions,[1, 2] expressions of opinion have been given relative to the general nature of the problem and methods of treatment. In this study, however, my more mature conclusions are set down, as well as some of the important clinical evidence which supports them.

Many cases falling within the general classification of the dwarfed mandible have not received the most effective treatment, because oral anomalies, frequently diagnosed as "malocclusions," have been treated solely upon a "tooth relation basis." In other words, in spite of the frequent assertion that orthodontic problems are chiefly dependent upon growth and development, the denture itself has been treated as an isolated object, with its dental relationships only being considered. In keeping with this idea, dental malocclusions, referred to as "Class II" cases, have received exactly the same treatment as those where, in addition to this type of dental anomaly, the mandibular structures were markedly deficient in size, and shared with the teeth an abnormal functional and anatomical relationship to the facial structures.

In presenting a previous study, it was shown that any diagnostic procedure based solely upon the anteroposterior relations of the molar teeth does not give an accurate picture of the pattern of the mandible, for growth aberrations in this bony structure may be found as the accompaniment of all the distinctive types of improperly occluding teeth. In Fig. 1, this statement is fully confirmed.

One is safe in assuming that the dwarfed mandible is the result of influences which have restricted its growth so that the normal pattern provided by the individual's hereditary tendency has not been fully attained. It shows a wide variation in the degree in which it is manifest, a fact soon apparent if standardized methods of recording cases are employed. This is comprehensible when one considers that all cases have not been subjected to the same influences or causes, nor have these causes been in effect through similar inter-

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vals of time, for they may have become operative before birth or at any subsequent period previous to the completion of body growth.

We may attempt a further generalization of the factors responsible for the dwarfed mandible by stating that these lie in the dual field of heredity and environment. To say which is the more responsible would revive an age-old controversy which now seems to be reconciled to the compromise that heredity determines how far an organism can develop, while environment

Fig. 1.—A study in mandibular patterns. Upper row: Mandibular structures within the range of the normal, but with all dentures having lower dental posterior malrelationships. Center row: Dentures similar to those in the upper row, but with dwarfed mandibles. Lower row: Molars and premolars in correct anteroposterior relationship, but with mandibular structures exhibiting characteristics similar to those shown in the center row.

determines whether it will ever get there. T. Wingate Todd,[3] one of the most celebrated anatomists of our time, said that "the physical pattern of the individual is enhanced, warped, dwarfed, or mutilated in its expression by the effects of environment."

In a paper before this organization last year, Pollia,[4] in discussing the growth problem, ventured the opinion that "the human organism rarely ever achieves the limits established by heredity," an observation which should give encouragement to those in the field of dentofacial orthopedics, for we cannot change a patient's hereditary possibilities, but we can so alter the environmental factors that those controlled by heredity can do indispensable work for us. This same investigator further emphasized certain fundamentals of growth by showing that "living cells have but one purpose, and that is to work. This inaugurates a remarkable chain of events, for to live is to work; to work is to eat and metabolize; to metabolize is to become larger; and to become larger precipitates growth." In the consideration of this special problem, where supplemental growth must be obtained, we are, therefore, brought face to face with two essential factors; i.e., function and metabolism, both of which must be fully employed. These are our special weapons, and in the degree to which they are utilized and controlled will we successfully meet the problem of the dwarfed mandible. Such a generalization seems simple enough, but when these two factors are fully considered, we find in each an enlarging field touching many phases of the living organism which are physical, chemical and psychologic in character.

"Metabolism[5] is the sum total of the enormous physical and chemical transformation which takes place in the body as it converts raw materials, known as food, into its own protoplasm." The foods essential to metabolism are proteins, fats, carbohydrates, water, minerals, and vitamins, and tend, under normal conditions, to promote growth and maintain health; but pathologic agents such as bacteria, injuries, and adverse environment, prevent these two functions and under a disturbed metabolism the disruption of the biologic mechanism which constitutes the body interferes with the effectiveness of our other weapon, function.

Even in apparently healthy children the demand, so far as food requirements are concerned, is frequently not wholly met. If we consider the daily minimum requirements to be,[5] let us say, one quart of milk, two eggs, three slices of whole wheat bread, two green salads, one orange or its equivalent in other fresh fruit, one portion of meat equal to a lamb chop, four tablespoons of leafy or yellow vegetables, and then check these against what our patients actually consume, we can readily understand how the human chemical equation is frequently far off balance.

In the matter of vitamins, we know that all are essential to the growing child and are doubly so with orthodontic patients where osseous changes of importance are taking place. Any insufficiency may be felt, especially of vitamin B_1, for supplemental growth, so essential in the treatment of dwarfed mandibles, must have this, if satisfactory progress is made. Experiments carried on, both with animals and with humans suffering with retarded growth, have proved its outstanding importance. It occurs in the ordinary foods men-

tioned, such as milk and green salads. This should be supplemented with vitamin D, and if outdoor life, with regular exposure to sunshine is not possible, may be supplied by giving ten to twenty drops of viosterol daily.

During recent years, much emphasis has been put upon the glands of internal secretion, and to their dysfunction are attributed numerous growth aberrations. Doubtless, "these regulators" constitute one of the interlocking chemical dependencies in the field of metabolism, and play a part in either its normal or pathologic manifestations. Unless the glands have undergone structural alterations, the most rational avenue of control of this sometimes "stormy element" lies within the field of nutrition, as attested by investigators of such eminence that their findings may be accepted as offering the safest and sanest methods up to the present time.[6]

In emphasizing the importance of normal metabolic sequences in our field, and the necessity of maintaining them through a rational nutritional program, mention must again be made of the fact that in a big majority of our patients, minimum food requirements are not met with regularity. This may be easily verified by having a group of patients write out in detail the amounts and character of foods consumed during a two-week period. Omissions in many instances will prove startling and make the investigator wonder why glaring clinical signs of malnutrition do not more frequently appear. We may also note a neglect of such ordinary hygienic practices as elimination, recreational exercise, routine rest habits, and other things favoring the normal physical, mental and emotional life of the growing child. The orthodontist must, therefore, frequently take on the multiple role of physician, psychologist and teacher, in an effort to gain a reasonable degree of cooperation. Such efforts are not always fruitful.

Let us now consider the other method of attack upon this growth problem, which is function. This is a more familiar field, for we have used it since the inception of our specialty. Its effectiveness, however, is dependent upon the skill and thoroughness with which it is applied, which naturally means that results will vary with individual orthodontists and patients. It will also be further conditioned by the age period when it is applied, for the response to this form of stimuli is more effective during the time when rapid growth changes should take place in the face.

A further conditioning influence comes into play during the active period of orthodontic intervention, when the teeth, dental arches, and jaws are being placed in what we may term the "normal functional range." Unless this is accomplished promptly and old habits of malfunction are eliminated and replaced by normal habits, a most important source of aid is weakened or nullified. This is the time of golden opportunity when definite aggressive measures count for much. All too frequently patients pass through a type of treatment best described as "wishful thinking," which starts nowhere, and ends at a well-known terminus known as "failure."

When appraised in its correct perspective, this phase of treatment necessitates not only skill of a high order in orthodontic technology, but that of equal degree in psychologic approach in directing the patient in developing normal functional habits. Even in their best form, these have limitations, for

here again heredity sets limits beyond which we cannot go. The functional habits of each individual, whether they be manifest in walking, speaking, general bodily posture, the mastication and swallowing of food, and other functional acts having a bearing in our field, are carried out in keeping with the germinal foundation provided by ancestors. We find in them, therefore, a variety of intensity and form, even though certain fundamental requirements appear to be complied with. Most individuals smile, but whoever saw two smiles exactly alike, except perhaps in identical twins, and even slight variations in these cases may often be detected.

In normally developed individuals, the effect of variations in the masticatory habits is frequently apparent through the careful analysis of the facial and oral structures where definite asymmetries may be detected. While entirely within the physiologic range, these may include differences in length and thickness of the two halves of the mandible, and the corresponding muscles supplying functional action. This is an important observation frequently overlooked.

Prosthetists, and others interested in restorative dentistry, frequently criticize orthodontists because they fail to bring about dental occlusal results which meet the same standards of balance supplied in artificial dentures, or full mouth restorations in adult patients. They fail to realize that their problem may be solved by supplying tissues and structures in artificial form, while the orthodontist must depend upon growth responses to supply deficiencies which may be necessary to establish so-called "balanced occlusion." Obviously, nature does not always respond with the same promptness as does the delivery boy from the dental supply house, nor can tooth length or alveolar increase or decrease be determined by a laboratory technician. As a matter of fact, there are times when the delivery made by Mother Nature falls short of what we may hope for. That, however, is not always the fault of the orthodontist, nor is he responsible for the nature of the problem he strives to solve.

Since all bones are plastic and alter their form in response to the demands made upon them, it follows that the mandible also modifies its outward form and internal structure when altered or increased requirements are made upon it. This is but another way of stating the fundamental biologic principle that form and function are mutually dependent, both in growing processes, and maintaining the equilibrium of bodily parts. It also serves as a supplemental explanation of Wolff's Law of bone transformation, which in brief is: "The amount of growth in bone depends upon the need for it."[7]

From these facts, and other evidence, the importance of establishing normal functional habits is rendered emphatic, especially when marked supplemental growth changes are essential. In this, the pressures resulting from muscle tone and pull are not only helpful, but necessary. In the matter of utilizing these in their most effective form, we can do no better than to follow the teachings of our own Alfred P. Rogers,[8] when he states, "The principles are: First, the mechanical re-establishment of arch form and cusp relation by the simplest mechanical means, thus removing any interference which tends to discourage the normal function of the muscles. Second, the principle of

muscular balance and mechanical advantage in the complete organism, including special guidance and control of those muscles concerned in the particular weakness upon which our attention is to be directed, urging them on to their normal development and strength until the harmoniously developed face completes the restoration of the organism to its normal inheritance." These are prophetic words, indeed, for they point the way to at least one major source of help in this problem.

In the treatment then, we are confronted with several factors, all of which may work for us, or if misdirected or not utilized may be the nemesis of our aims. These are heredity, metabolism, and function. The first, heredity, sets limits beyond which we cannot go. It is our task to see that these limits are fully attained; the second and third are the real "conditioners," for they open the pathway and determine how it will be traveled. We proceed then as follows: Patients not under the routine care of the family pediatrician are urged to take every step necessary to establish metabolic balance and thereby become "favorable orthodontic risks." Especially in the field of nutrition is the request made for cooperation. While response is often disappointing, this avenue offers a direct means of attack, and when basic requirements for the average case are so simple, instructions are not difficult to follow. With improved health, frequently injurious "habit spasms," such as those involving the lips, tongue, cheeks, etc., will be eliminated, and other pressure habits of external origin can more easily be conquered.

As soon as the time arrives when intermaxillary traction can be applied, an important initial step in the retraining of essential muscular groups is inaugurated, for in seeking relief from this form of pressure the mandible is moved forward. This is the beginning of a period of adaptation, and changed manner of use which is very helpful to additional measures in more concentrated form which are applied as soon as the teeth and dental arches are brought within the normal functional range. At this time definite exercises, involving the temporal and masseter groups and the pterygoids, are started, so that these muscles, which formerly were adapted to malrelated structures may become readapted to the new improved relationships. Following this, the exercise for general facial development is added, with the idea of bringing the orbicularis oris and the various facial muscles attached to it, up to normal tone and function.

In all of the tasks outlined so far, the cooperation of patients constitutes one of the important determining factors. It is unnecessary to point out that in most instances this fails to reach the degree we hope for. This does not change the nature of our problem, nor the only method of approach open to us at the present time. A few illuminating exceptions supply the stimulus which makes us carry on.

In reporting a series of cases, I do so not with the idea of showing spectacular results, but rather how variable these may be. The dental anomaly in every instance was similar, in that all the lower teeth occupied a posterior malrelationship. The positions of the maxillary incisors varied. Each case has been recorded over a number of years, and the sequence of records demonstrates the general nature of growth responses. A photostatic clinical camera

has been utilized throughout the entire period, with size ratios constant at one-half life size. Gnathostatic casts record the dentures so that their relation to the facial structures is shown, as well as the angle of the occlusal plane, tooth inclinations, and the symmetry or asymmetry of opposing parts. In each case the second facial record was made at the time the teeth and jaws were brought within the normal functional range. Subsequent records show the supplemental growth which follows this essential aim of treatment. A standardized plan of charting the photostatic records has been used so that changes will be more easily visualized. This method is shown in Fig. 2. Accurate tracings of the photographs were then added (Fig. 3), to show more clearly the extent and nature of anatomical changes, and horizontal and vertical lines carried through standard measuring points to aid this objective. Only a brief but relevant number of items will be covered in each report, these being; (1) sex of patient; (2) age; (3) mandibular pattern of parents; (4) number of children in family and dental anomalies, if any; (5) period of treatment necessary to approximate normal function; (6) cooperation of the patient; (7) subsequent growth changes; and (8) the status of the third molars.

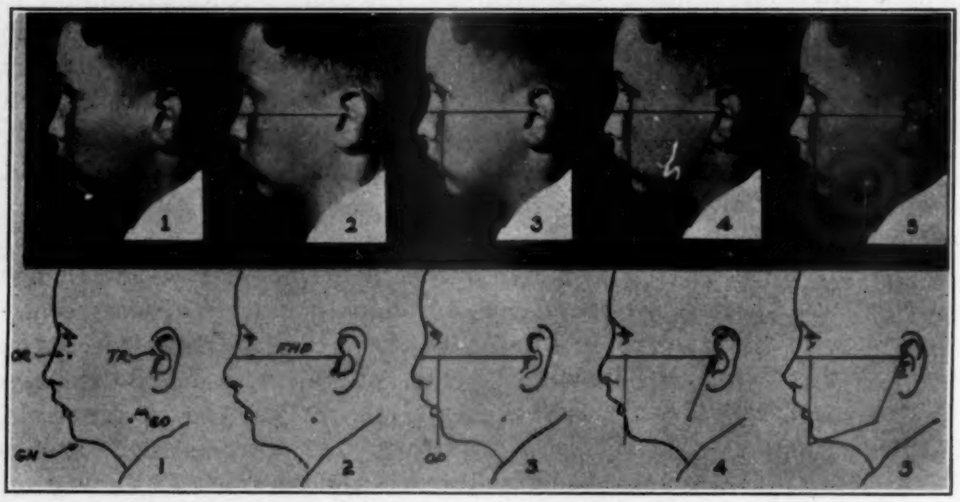

Fig. 2.—A series of photographs and drawings showing the method of charting photostatic facial records. First, the Frankfort horizontal plane is established, then the orbital plane, followed by the lineal representation of the mandible. *OR*, orbitale; *TR*, tragion; *GN*, gnathion; *GO*, gonion; *FHP*, Frankfort horizontal plane; *OP*, orbital plane.

CASE 1 (Fig. 3)—A boy 9 years and 9 months of age; mandibular pattern of both parents normal; an only child; period of primary* or active treatment, eight months; period of secondary treatment, approximately three years; cooperation, fair; marked growth in body of the mandible during primary treatment; during secondary treatment, and following it, increased vertical growth is reflected in the rami and the other facial structures; the third molars unerupted but in normal positions.

CASE 2 (Fig. 4)—A boy 8 years of age; 1 … 1 of both parents normal; an only child; period of primar… …teen months;

*The phase of treatment during which the teeth, d… …nd jaws are restored to normal form and function. Following this, post-treatme… …ecessary. This is designated as "secondary treatment."

period of secondary treatment, four years; cooperation, good; marked growth in the body of mandible during primary treatment; during secondary treatment, and following it, marked vertical growth changes; third molars will erupt normally. The more faithful use of the exercise for general facial development would have produced growth in the mentolabial sulcus, the need for which is apparent.

CASE 3 (Fig. 5)—A boy 8 years of age; mandibular pattern of both parents normal; one of five children, three of whom had eugnathic anomalies, and two with dysgnathic anomalies similar to those being reported; period of primary treatment, twenty-one months; period of secondary treatment, approximately three years; cooperation, poor; mild growth responses during primary treatment; during later part of secondary treatment marked improvement in cooperation occurred, with helpful growth responses immediately apparent; the third molars are unerupted, but in normal positions.

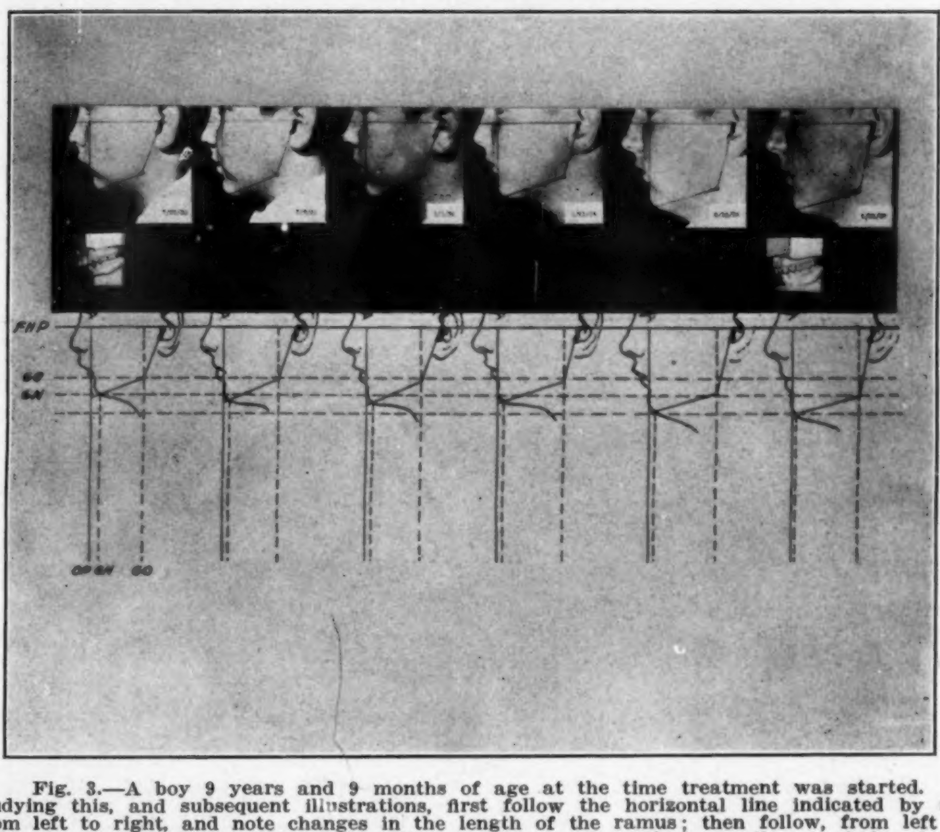

Fig. 3.—A boy 9 years and 9 months of age at the time treatment was started. In studying this, and subsequent illustrations, first follow the horizontal line indicated by *GO* from left to right, and note changes in the length of the ramus; then follow, from left to right, the horizontal line *GN*, which will reveal increased vertical growth. A study of the vertical lines, represented by *OP* and *GN*, and their relationship to the vertical line *GO* will reveal growth changes in the body of the mandible. Other alterations of interest may be noted from the study of the combination of vertical and parallel lines.

CASE 4 (Figs. 6 and 7)—A boy, 9 years of age; mandibular pattern of both parents normal; one of three children, all with similar dysgnathic anomalies, as shown in Fig. 6 (two of these cases will be included in this report); period of primary treatment indefinite, but approximating three years; period of secondary treatment still in effect; cooperation during first period very

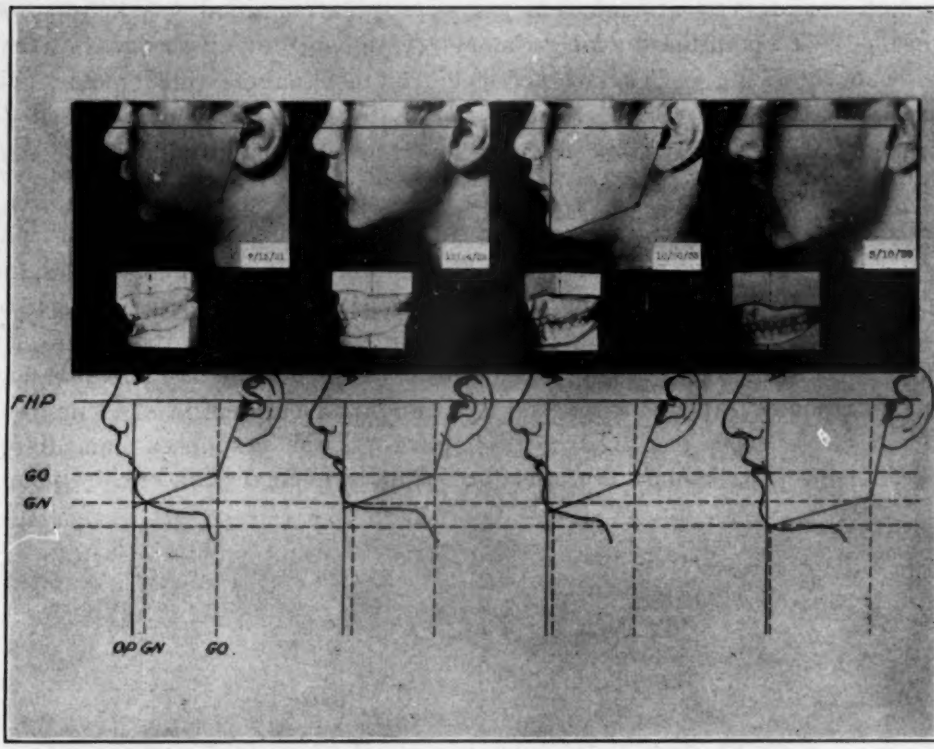

Fig. 4.—A boy 8 years of age at the time treatment was started.

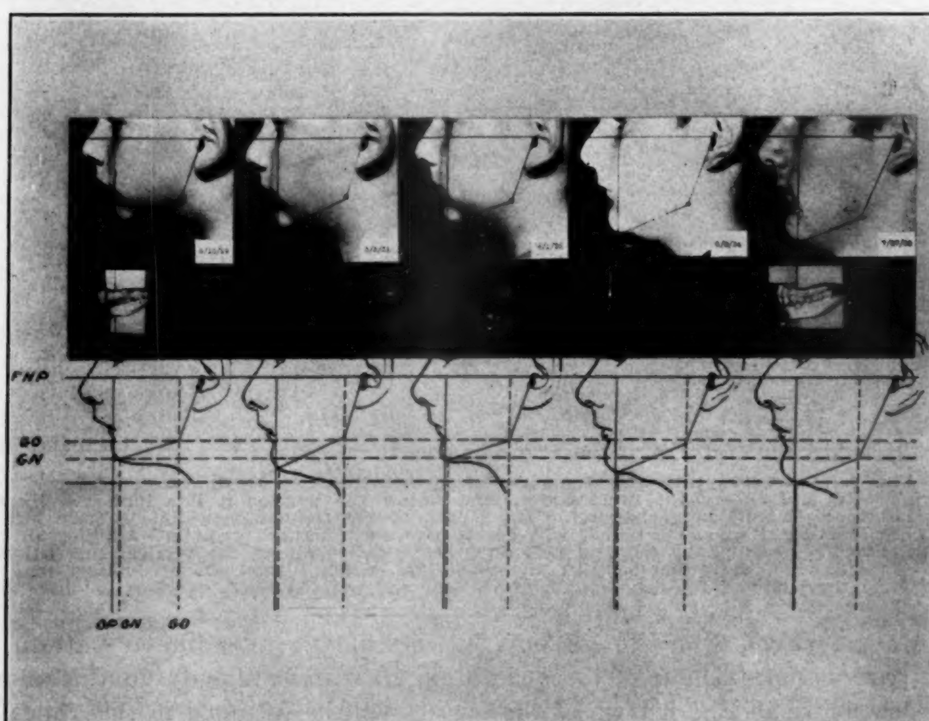

Fig. 5.—A boy 8 years of age at the time treatment was started.

poor; little change in the pattern of the mandible up to the present, other than vertical growth in the face; the third molars badly impacted and will require surgical removal.

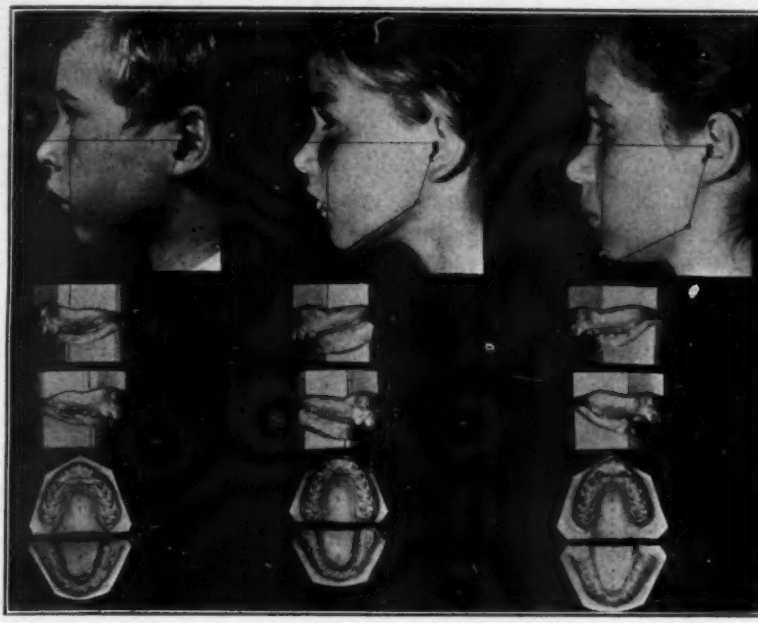

Fig. 6.—Three children in the same family, all with similar dysgnathic anomalies.

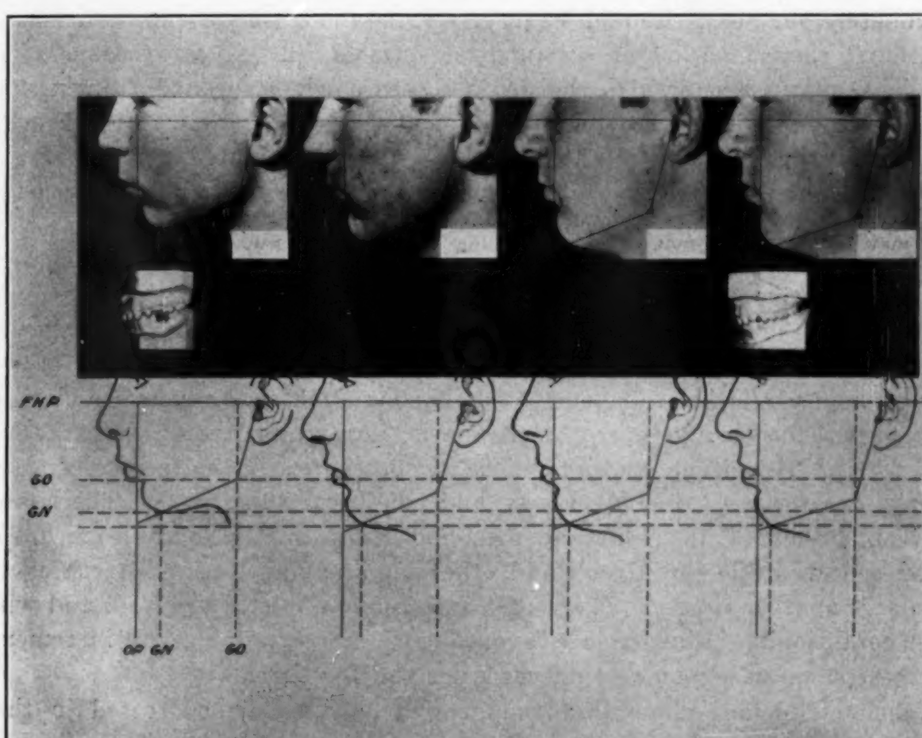

Fig. 7.—A boy 9 years of age at the time treatment was started.

CASE 5 (Fig. 8)—A girl 9 years of age, and a sister of the boy shown in Fig. 7; period of primary treatment, fifteen months; period of secondary treatment, approximately three years; cooperation, excellent; marked growth in rami during primary treatment; during secondary treatment general facial growth favorably augmented; third molars unerupted but in normal positions.

CASE 6 (Fig. 9)—A boy 13 years of age; mandibular pattern of mother normal, while the father had a dwarfed mandible, mild in degree; one of three children, two of whom had similar anomalies; period of primary treatment, two years; period of secondary treatment, approximately four years; cooperation, excellent; marked growth in all portions of the mandible during primary treatment; during secondary treatment continued favorable growth in the mandible occurred, and in the facial area, vertical growth being especially apparent; the third molars appear to be erupting normally.

CASE 7 (Fig. 10)—A boy 9 years of age; mandibular pattern of both parents normal; one of two children with similar anomalies, the other less severe than this one; period of primary treatment, less than one year; period of secondary treatment, approximately three years; cooperation, excellent; marked growth in both the body and rami during primary treatment; during secondary treatment, this was supplemented with marked vertical growth in the face; the third molars in normal position but unerupted.

CASE 8 (Fig. 11)—A boy 9 years and 6 months of age; mandibular pattern of both parents abnormal, but mild in degree; one of two children. The other, a girl, has a eugnathic anomaly; period of primary treatment, approximately one year, although in three months the teeth were in their normal functional range; period of secondary treatment, three years; cooperation, excellent; marked growth in the mandible, as a whole, occurred during primary treatment; during secondary treatment this was supplemented throughout the entire facial area. The third molars are unerupted, but apparently in normal positions. This patient was under careful medical guidance throughout the entire period of treatment.

In studying these records, it is of interest to recall many discussions in the past relative to the manner and location of mandibular changes; viz., whether these occurred in the glenoid fossae, at the angle, or in the alveolar portions of the bone. Had accurate methods of recording clinical results been in use, these would have demonstrated that mandibular patterns are changed with growth occurring in any of its parts, depending upon where there is need for it. This organ grows from six ossific centers,[10] one for the condylar process, one for the coronoid process, and another for the angle. The regions between the mental foramina and the inner surface of the body, each has an ossific center, while the alveoli and other bony supports of the teeth evolve from still another source. Therefore, during a suitable age period, and when other conditioning influences are favorable, we may expect growth increments, for these come in response to nature's demand for them.

Some clinicians claim that the growth changes demonstrated in these cases would have occurred regardless of orthodontic intervention. Such an assumption, however, will not stand the test of critical analysis. Growth

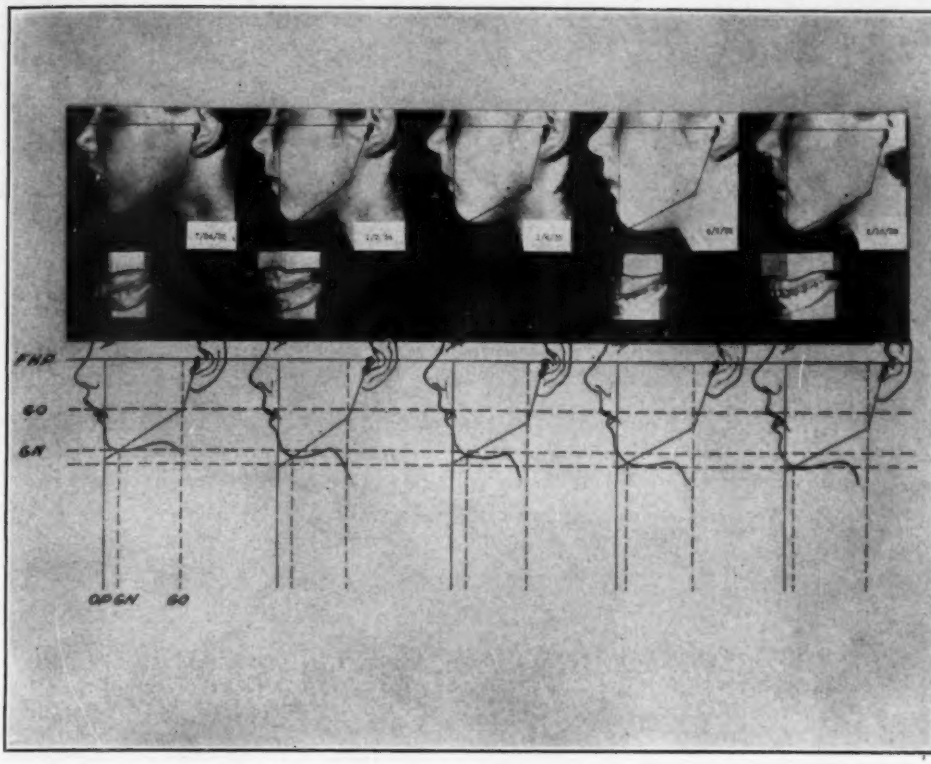

Fig. 8.—A girl 9 years of age at the time treatment was started.

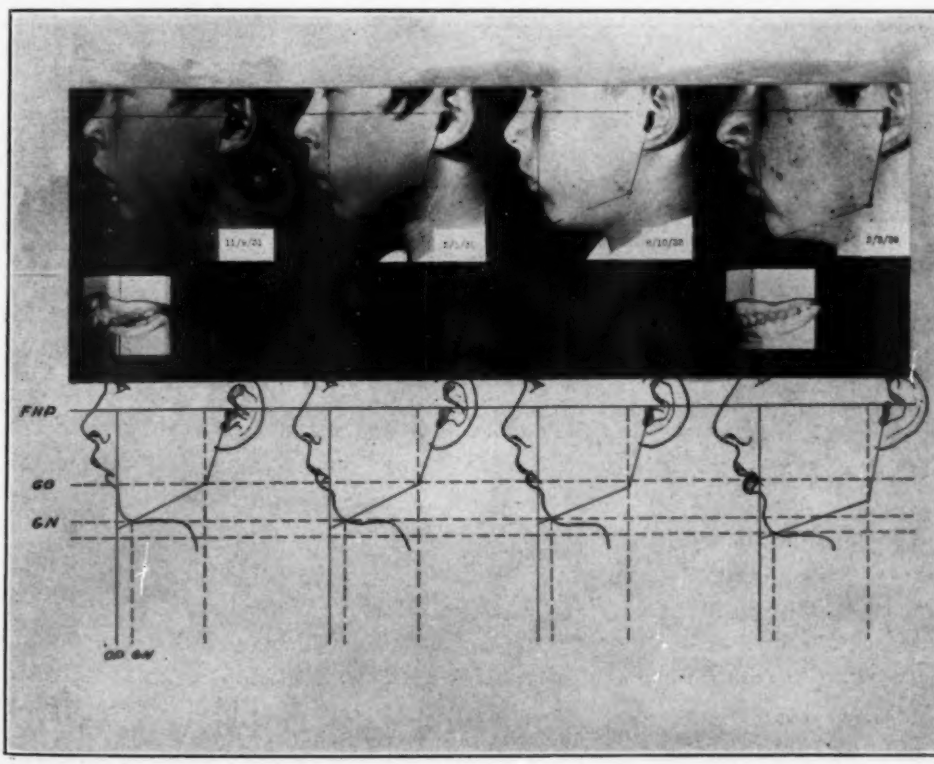

Fig. 9.—A boy 13 years of age at the time treatment was started.

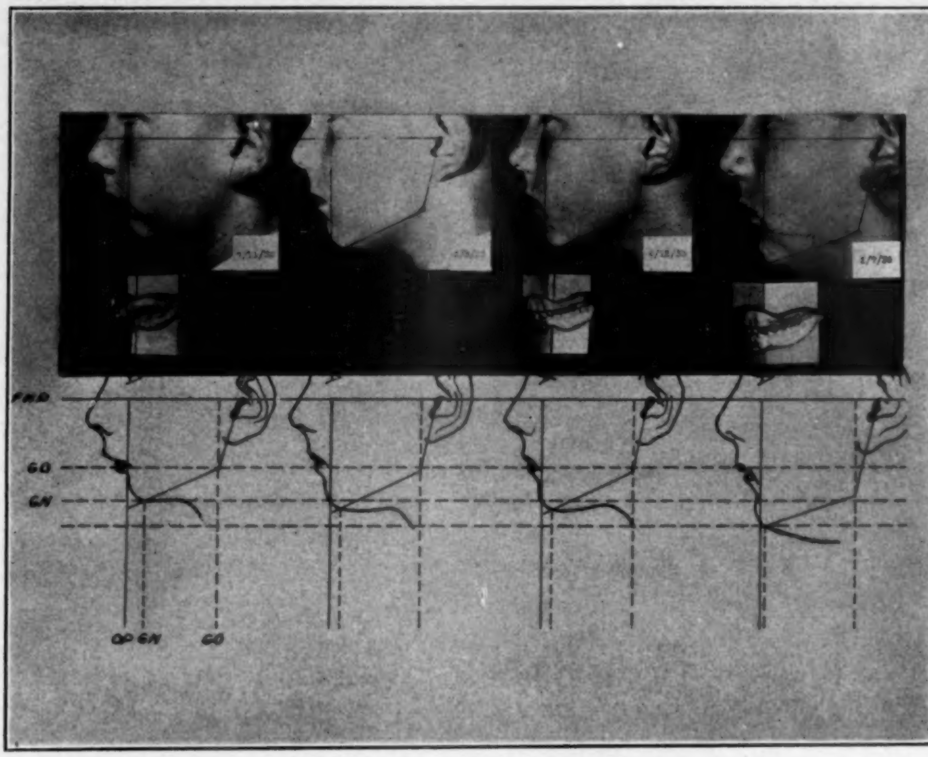

Fig. 10.—A boy 9 years of age at the time treatment was started.

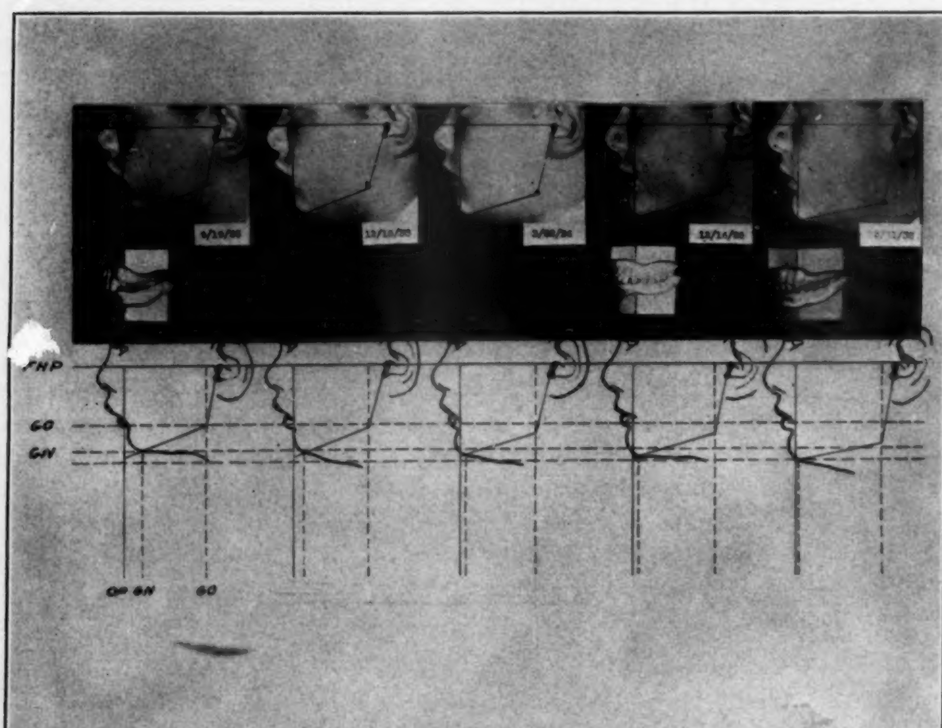

Fig. 11.—A boy 9 years, 6 months of age, at the time treatment was started.

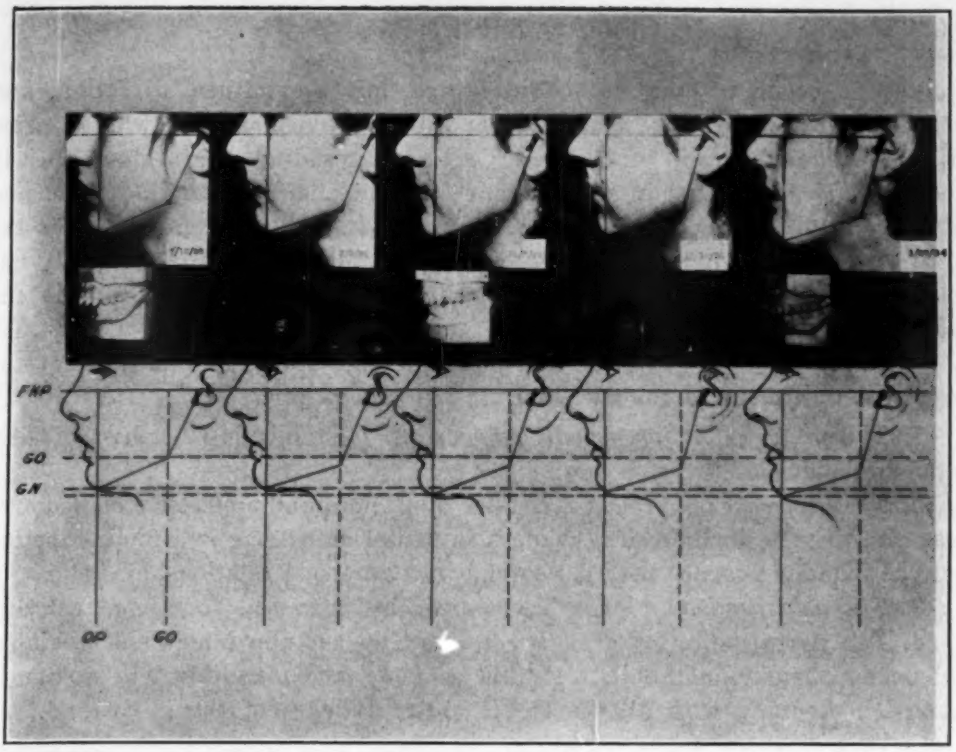

Fig. 12.—A girl 13 years of age at the time treatment was started. Mandibular pattern normal and unchanged by treatment.

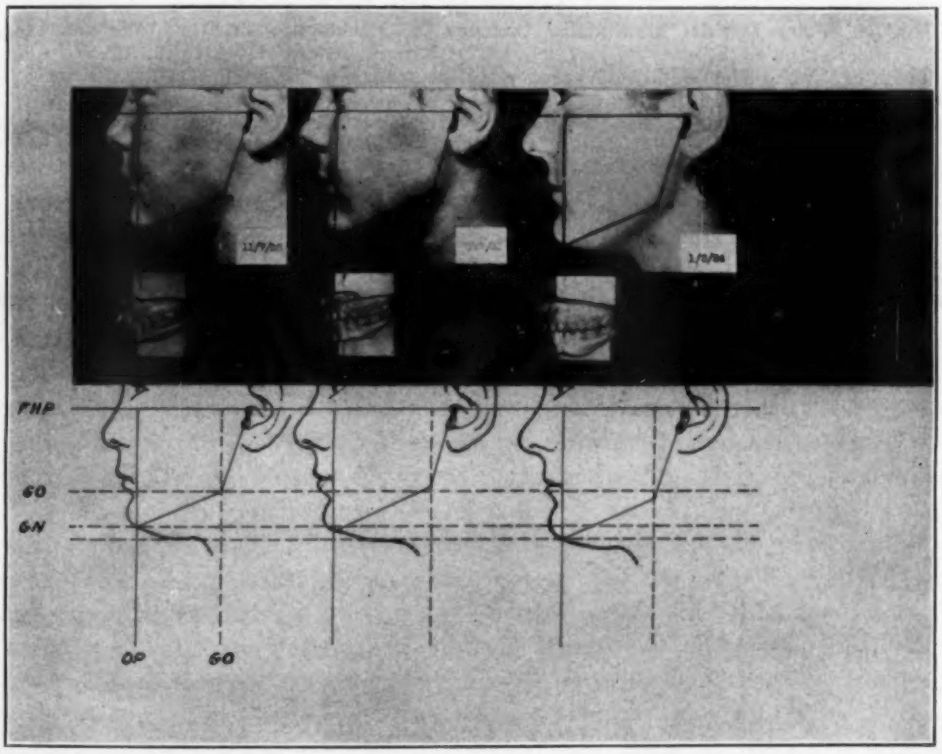

Fig. 13.—A girl 8 years of age at the time treatment was started. Mandible normal and unchanged by treatment. This illustration is also used to show the importance of establishing measuring points correctly. In this instance the gonion spot is not properly located, hence the lineal representation of the mandible is incorrect. The correct location of the gonion is indicated.

changes do occur without orthodontic care, but the nature, direction, and pattern of such changes are quite another thing. To demonstrate what I mean, I will now show a group of six cases,* all having similar dental anomalies to those already shown, but in each instance the child had a mandible of normal pattern. In these cases it will be noted that what I have referred to as the "pattern" has not changed with treatment, although the dental anomaly has been corrected. Vertical growth in some cases has taken place, but in the main, facial architecture is unaltered.

We may briefly summarize and conclude this study by stating that the successful treatment of the dwarfed mandible requires:

1. *The preparation for growth responses,* by establishing the best possible metabolic balance.

2. *The necessity for growth responses* by prompt and aggressive orthodontic measures, these to include such changes in dental arch form and tooth function that the mandible can be moved forward into a normal relationship.

3. *The achievement of growth responses* by increased functional activity.

4. *The perpetuation of growth responses* by sustained metabolic balance and normal functional habits. If this be done, the mandible will assume a pattern in keeping with all the rights and privileges of the individual.

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*Only two of these cases will be published because of their similarity; these appear as Figs. 12 and 13.

SOME FACTORS INVOLVED IN THE TREATMENT OF ANGLE'S CLASS II, DIVISION 2

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Angle in his classification of malocclusion of the teeth describes Class II, Division 2 cases as "characterized specifically by the distal occlusion of the teeth in both lateral halves of the lower dental arch, indicated by the mesiodistal relations of the first permanent molars, but with retrusion instead of protrusion of the upper incisors. In this division there are no complications from pathological conditions of the nasal passages, hence the mouth is kept closed the normal amount of time, and the lips perform their function normally, which causes the retrusion of the upper incisors during their eruption until they come in contact with the already retruded lower incisors, resulting in a crowding of the upper teeth, in the canine region."[1]

It seems expedient to state the objective of this paper before entering upon the discussion of factors involved in the treatment of this type of dental aberration. No attempt will be made, nor is intended, to advance any startling innovations in the treatment of this type of malocclusion, but rather to evaluate and correlate factors which present themselves for consideration when one is called upon to cope clinically with this form of dental anomaly.

A review of orthodontic literature leaves one amazed at the dearth of discussion on this type of malocclusion. This can be explained by the lack of the dramatic when results of treatment in this division are compared with those frequently obtained in Division 1, that its percentage of the total of malocclusions is relatively small, and that the results of treatment are attended by no great degree of uncertainty. Nevertheless because this type of malocclusion does present its problems even to practitioners of mature experience, benefit can be derived from a discussion of them.

It is only natural that we select etiology as the first factor for discussion for as Sim Wallace points out, "nothing is more certain than that a correct appreciation of the etiology of the irregularity of teeth helps materially in diagnosis and treatment."[2] It is also true that within the last one or two decades this phase of orthodontics has enjoyed a large share of the original thoughts and contributions made to our specialty. As a result of these many individual and unassociated researches and investigations, unless care and thought are exercised in order that the question of etiology be considered as a whole rather than as a series of unrelated parts, such as hereditary, environmental, general, and local factors, one can easily be dismayed and discouraged of ever attaining such a correct appreciation.

In etiology much of what had formerly been accepted as fact is now considered with reservation. The manner of assurance with which the various types of malocclusions were once ascribed to definite etiological factors has

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given way to a feeling of uncertainty. One can venture to attribute this seemingly chaotic condition of mind to two possible factors. First, an increasing consciousness and understanding of the phenomena of growth on the part of the orthodontic profession as a whole and, second, to the influence of Brash's[3] monumental work on etiology. The former because it has taught us that in the dentition we are dealing with a dynamic and not a static object, and that its growth is normal within a certain range of variation. The latter because it is all too frequently viewed as a destructive rather than, as Brash intended, a constructive criticism of etiology. Therefore, unless care is used to precisely understand Brash's viewpoint, one can erroneously be led to believe that he disposes of practically all current concepts of etiological factors of the time as mere suppositions. Careful study indicates that this was far from his real intention. Although he does question their specific influence, he does not disregard environmental forces which comprise the major part of our concept of etiology, but recommends hereditary forces be as carefully considered. From his conclusions it appears that the proper interpretation should be that, with a few exceptions, environmental forces are not singular in their action but complementary to more deep-seated forces phylogenetic in origin. This viewpoint is consistent with the recent work done in the field of growth and development.

The respective degree to which environmental and hereditary forces enter into the composite picture of etiology of malocclusion is at present a mooted question. Its solution is eventually dependent on factual evidence forthcoming from the laboratories of those working in the field of genetics.

As a result the above mentioned factors, instead of tending to confuse the issue of etiology, should definitely aid in a clearer and more comprehensive appreciation of it, causing us to be more scientific and less empirical in our appraisal of etiological factors.

Now let us consider the specific etiological factors which have been associated with Class II, Division 2 cases. Earlier reports and textbooks dealing with this type of malocclusion are rather vague in their exposition of causes, generally attributing the condition to the premature or late loss of deciduous teeth, posture habits, and to a lack of growth in the mandible. Compared to Division 1 of the same class, its association with certain distinct etiological factors has never been as definite. Lip function being normal, it has invarably been assumed that muscular action has little influence on the occlusion except in the lingual displacement of the maxillary incisors, particularly the central ones.

It is interesting to note the report on a questionnaire submitted to a group of orthodontists, requesting that all etiological factors found associated with Class II, Division 2 cases be enumerated. The report listed the following:

1. Perverted functional activity of the muscles of the lips effecting a backward driving force.

2. Excessive action of the mentales muscles, either in a habit spasm or sucking action.

3. Perversion of the swallowing function, especially the first stage, in the form of exaggerated sucking action.

4. Premature loss of deciduous molars.

5. Hypertoned, tense musculature of lips.

6. Hypertrophy and overdevelopment of the musculature of the cheeks.

7. Nervous, high strung temperament.

8. Malnutrition in early infancy pointing to disturbance of calcium metabolism.

9. Hypertrophy of the mentales muscles is almost universal in these cases.

10. Distal pull by muscles attached to hyoid bone.

11. Posture habit.

12. The retarded forward growth of mandible due to muscular pressure, a constitutional condition or both.

After considering these replies in open meeting the group concluded: "In these answers we believe that we have something to offer for your consideration. None of the writers, up to date, seem to have recognized the extreme perversion of the musculature that is present in these cases. They all speak of the muscles as acting normally. In reality they are hyperactive muscles.

"The etiological factors that seem to be associated with these cases are, primarily, a failure in metabolic or developmental processes resulting in lack of vertical growth in the molar and premolar regions of the dentures and, secondarily, a perversion of the sucking function which leads to an abnormal degree of growth and development of the sucking muscles particularly manifested in a hypertrophy of the mentales muscles. These hypertrophied and abnormally acting muscles produce distal pressure upon the anterior portion of the body of the mandible and sufficient retardation of the forward growth to effect a distal locking of the mandibular molar teeth. From then on the forces of occlusion aid in checking the forward growth of the body of the mandible."[4]

Aside from being in agreement with the existing concept that this form of dental anomaly is principally associated with deep-seated causes of disturbed growth, the conclusion of this report merits consideration because, as the authors suggest, perhaps here for the first time we have a suggestion that a perverted musculature can be identified as a secondary factor in producing this type of malocclusion. That a perverted musculature is evidenced is within the bounds of possibility because form and function are inseparable but its acceptance, even as a factor active in the secondary sphere of influence, will, in the last analysis, depend on whether further clinical observation will establish it as an etiological entity or as a concomitant symptom.

It is possible in Class II, Division 2 cases, that form is the determining factor. To state it more clearly, is it not probable that in this type of malocclusion the habit of swallowing and its ensuing muscular unbalance are the direct result of alteration in structure? This can bear consideration for habits in cases of Division 2, unlike those of Division 1, seem to be spontaneously overcome when the structures have been placed in a functional relationship.

Reflecting on the etiology of Class II, Division 2 malocclusions, it appears to the writer that the attainment of a comprehensive understanding of the causative factors involved depends largely upon a true appreciation of the particular nature of developmental growth which is peculiar to the individuals possessing this form of dental anomaly.

Hellman[5] in his study of Class II malocclusions found that while Division 2 cases are accelerated in the differentiation of the dentition, until the time for eruption of the second permanent molar, after which retardation sets in, there is a definite lag in the height and weight increment of these individuals as compared to those of Division 1, where the reverse is true. He does not generalize when he speaks of the tempo of differentiation of these cases, but in the absence of factual evidence, if this can be taken as a coefficient of the developmental progress of the organism as a whole, two interesting conclusions can be made. First, it is possible to consider these cases as individuals in whom developmental growth has been disassociated, development at the expense of growth. Second, while developmental progress, the more significant of the two phenomena, is conditioned solely by ontogenetic factors, growth or dimensional increase may be conditioned by either phylogenetic or ontogenetic factors. Therefore, our quest of etiological factors of Division 2 cases should be directed to both hereditary and environmental factors.

As was previously stated, due to the meagerness of factual evidence, the orthodontist is necessarily handicapped in his search for hereditary factors. The mere witnessing of a like condition in either or both parents cannot in itself be conclusive in establishing the malocclusion under consideration as of phylogenetic origin. Nevertheless the possibility of hereditary influence must always be recognized.

In contrast our search for the primary factors of environmental origin has been considerably facilitated as a consequence of the intensive work done on the problem of growth and development. Todd[6] has shown that the critical period of developmental growth lies within the first two years of life, for it is within this short space of time that its tempo is established. It would, therefore, appear that a careful scrutiny of this period is important. Any factor which would interfere with the general metabolic processes during this time must be suspected.

While nutritional disturbances resulting from inadequate and ill-suited diet, prolonged fevers, and allergic tendencies are the most common causes, facial injuries must also be considered.

If etiology is conceded to be the major pitfall which confronts the orthodontist in the treatment of all types of malocclusion, then it is equally true that in dealing with Class II, Division 2, diagnosis is of almost equal importance. This is particularly true if diagnosis is to assist in the formulation of the plan of treatment. Whether it should is beyond the limitations of this discussion, but because the plan of treatment is influenced either consciously or unconsciously in the majority of practices by diagnosis, it would seem that a consideration of what diagnosis really signifies would be profitable.

Orthodontic literature indicates that much thought has been expended in the attempt to formulate a definition of diagnosis which in all ways would be adequate from the orthodontic viewpoint. Because of the many conceptions held and varying ideas of what the term implies, it would appear that there is some disagreement as to what an orthodontic diagnosis should embrace. Undoubtedly the difficulty arises from a too literal translation of a word borrowed from the practice of medicine, rather than the application of the basic principles involved.

Two factors are essential to any diagnosis. The first, a clear conception of what the form and function of the organ or part being diagnosed should be within its standard range of variation. The second, some convenient means that may be regarded as a yardstick by which conditions falling outside the pale of the standard range of variation can be evaluated.

Since occlusion has assumed biologic significance, it has not been a simple matter for the orthodontist to acquire a comprehensive understanding of what constitutes normal. The time is past when occlusion can be regarded in a static sense and as totally dependent on occlusal relationships. Today, we recognize that the occlusion of an individual is in a constant state of change throughout life, functional in nature and modified by many of the same factors which govern the growth and development of the organism as a whole.

Friel, Lewis, and Broadbent in their observations on growing children have conclusively demonstrated that many of the conditions which seemingly appear as malocclusions are, in reality, stages in normal growth and development.

In the absence of any definite rule as to what constitutes a malocclusion, it must of necessity, for the present at least, remain largely a personal equation into which the experience of the operator enters in a large degree. Therefore, it would appear that the only way toward a workable conception of normal for the clinician lies in the direction of continued application to the problem of growth and development by means of studying all available reports on investigations conducted in this field, as well as the careful personal observation of patients placed in his care.

It is hoped that eventually the accumulation of knowledge will enable the establishment of a series of standard growth patterns for the various stages of development.

The other essential to an orthodontic diagnosis, namely, the selection of a yardstick with which to evaluate the deviations from normal, has also met with considerable uncertainty of late.

Angle's classification was universally accepted as such a means of appraisal until his hypothesis relating to the constancy of the first molar was refuted. Since that time other means have been recommended to fulfill this need. Notwithstanding, it seems that with some reorientation such as proposed by Strang, Angle's classification of malocclusion can reasonably satisfy the needs.

Strang[7] suggests that, instead of using inclined plane relationship as the concluding factor in the classification of malocclusion, primary emphasis be placed upon the relationship of the body of the mandible to the cranial anatomy; tooth inter-relationship can then be considered a secondary factor of importance, offering, "accumulative evidence for deducting the correct classification in complicated and doubtful cases and determining the logical plan of treatment."

Upon this premise he characterizes Class II, Division 2 as "cases of malocclusion in which the body of the mandible and its superimposed denture are in distal relationship to cranial anatomy, and in which the maxillary central incisors are in vertical or lingual axial inclination."

Realizing that the study of facial lines alone would at times be inconclusive in properly classifying a case, he recommends that the following six factors be noted as well.

1. A study of the inclined plane relationship.
2. A study of the axial inclination of each dental unit.
3. An analysis of the relationship of the interproximal line of the central incisors in the two arches and a comparison of these lines to the midsagittal plane of the head.
4. The noting of rotated buccal teeth, especially the maxillary molars.
5. A study of the intraoral and profile roentgenograms.
6. A study of the facial photographs, both the front view and each profile picture.

Using this classification, it can be readily seen that there cannot be two distinct types of Class II, Division 2 malocclusions as had formerly been supposed, but rather one which can be associated with a characteristic syndrome of symptoms.

The symptoms manifested by this type of malocclusion may be considered in two separate groups, namely, those observable in the facial lines and those discernible in the dentition itself.

Before discussing the symptoms of the first group, it would be well to briefly consider the physical aids requisite to this part of the diagnosis, for to merely visually observe the facial lines is inadequate. Most important are photographs of the front and side views. It is vitally important that the head be oriented in a position that places the eye-ear plane parallel to the floor of the room, otherwise a false conception of the true position of the mandible may be gained. To avoid obliteration of necessary details, these photographs should be no smaller than quarter size.

Profile roentgenograms are another valuable aid. Roentgenograms of this type are particularly useful in dealing with Class II, Division 2 cases, because of the deceptive appearance given the mandible by the frequently hypertrophied mentales muscles.

Upon evidence gathered by means of these aids, the following facial symptoms may be considered as typical in the facial lines of a Class II, Division 2 case.

(1) Without exception a distal relationship of the body of the mandible to the cranial anatomy.

(2) Invariably a subnormal total facial height mainly due to a lack of vertical growth in the premolar and molar regions.

(3) Invariably a rolled and thickened lower lip which ofttimes is accompanied by a horizontal skin crease in the mentolabial sulcus.

(4) Frequently, hypertrophied mentales muscles.

The symptoms observable in the dentition are:

(1) A distal relationship of the lower to the upper arch.

(2) A deep overbite associated with little or no curve of Spee. The occlusal surfaces of the buccal teeth are located in one horizontal plane, while the incisal edges of the incisors establish another that is parallel but somewhat occlusally related, the canine forming a step between the two.

(3) The mandibular arch is well developed buccolingually except in the canine region where it tends to be constricted. The molars and premolars are vertical to the occlusal plane and in infraclusion.

(4) The maxillary arch is well developed buccolingually and in most cases the axial plane of the molars and premolars is distally inclined. The incisors are either in a vertical position or lingually inclined.

It is apparent that a diagnosis based upon a classification and an aggregate of symptoms such as above outlined obviates the possibility or necessity of recognizing two distinctly different types of malocclusion within this division. As a result the value and necessity of a comprehensive diagnosis are enhanced for then it does not merely indicate whether treatment is feasible but aids as well in the formulation of a proper plan of treatment.

We should bear in mind before entering upon the discussion of treatment that there is no justification for any method of mechanotherapy in the clinical practice of orthodontics unless it is applied with the strict understanding that it shall constitute merely an incident in the treatment of malocclusion. Sometimes this incident is most important, and again at times it is a relatively unimportant item in the treatment. This is true because the objective of modern orthodontics is the restoration of form and function and neither of the two can be definitely restored by means of mechanical appliances. The real and definite re-establishment of form or of function is left to the workings of the inherent forces of the organism.

Perhaps the first consideration of major importance in the discussion of orthodontic treatment is the question of the most appropriate and advantageous age at which orthodontic therapy can be instituted.

A review of the literature clearly shows that when generalization had been attempted in the solution of this question, it was doomed to fail. In this respect our specialty has experienced the full swing of the pendulum. Neither postulate, early or late treatment, applied unreservedly has proved infallible. As a consequence the question must be individual in nature, primarily dependent on whether a condition of true malocclusion really exists, after which other factors subservient in nature should as well be considered.

In a like manner let us see whether, within certain limits, a preferred age for the treatment of Class II, Division 2 cases can be established. Lewis[8] in discussing deep overbite cases points out that while an extreme depth of overbite in certain types of malocclusion spontaneously adjusts itself, the deep overbite usually associated with Class II, Division 2 cases does not. Upon this finding alone, inference could be drawn that, because forward shifting of the mandible is not possible without an accompanying increase in dental height, a condition of malocclusion can be considered to exist in Division 2 cases at an early age. But due to the intensive state of change evidenced in the developing dentition between the physiologic ages of 8 and 10 years, the confirmation of malocclusion should be deferred until after the tenth year.

In the writer's practice, two additional factors are also considered. Clinical experience with these cases shows that the most uncertain part of treatment, the adjustment of the overbite, responds more readily to therapeutic measures when instituted between the ages of 11 and 13 years. While cases in this category are amenable to treatment, mechanical retention of the increased dental height through the period of growth that usually approximates the period of adolescence is frequently necessary. Therefore, if the possibilities for error are to be

minimized and the treatment simplified without a compromise of results, the preferred age for treatment of Class III, Division 2 cases can provisionally be established between 11 and 13 years.

While it is true that the plan of treatment will vary in accordance with the needs of the individual case, because certain structural alterations are so commonly possessed by anomalies of this type, it is possible to organize treatment in a series of more or less definite steps. These steps may be considered as four in number, three of a corrective and one of a retentive nature. They are:

1. Alignment of the maxillary teeth and elimination of all conditions within the maxillary arch which will act as points of interference in the forward movement of the mandibular arch.

2. Correction of the mesiodistal relationship of the maxillary and mandibular dental arches.

3. Correction of any excessive overbite accompanied by a final adjustment of the individual dental units with particular attention directed toward the correction of any rotations and improper axial inclinations present, to the end that the occlusal surfaces of the two arches are properly and intimately related.

4. Retention.

While in actual practice these several steps in the corrective procedure are not separate and distinct, but more or less blended into one another, it is nevertheless true that progress must be well along in each step before the treatment of the step following can be effectively initiated.

Concerning the various types of appliances that may be employed in the treatment of Division 2 cases, as in the treatment of malocclusion generally, the requirements of simplicity and efficiency are of first importance. It is true that many types of appliances are available to the orthodontist today, some whose construction and manipulation are more involved than others. Superiority is claimed by the proponents of each. But until a scientific appraisal of the results obtained by means of the various types of appliances is made, it seems that the simplest appliance is most desirable.

Although no special advantage is claimed for the following outline of procedure in the treatment of Class II, Division 2 cases, because it has proved efficacious in my hands, it is herewith presented for your consideration.

Treatment is initiated in both maxillary and mandibular arches with an appliance consisting of a removable lingual arch wire and plain round labial arch wire. The maxillary lingual arch wire is dispensed with when expansion in the maxillary canine and premolar areas is unnecessary. The first few adjustments of the maxillary appliance are chiefly concerned with the removal of all points of occlusal interference. Expansion of the maxillary canine and premolar regions is accomplished by means of compound auxiliary springs soldered to a cutback lingual arch wire. Alignment and intrusion of the incisors is obtained by means of ligatures and labial arch wire. When this phase of treatment nears completion, the correction of the mesiodistal relationship of the arches is started by means of intermaxillary elastics extending from hooks soldered to the maxillary labial wire in the canine regions to the distal ends of the buccal tubes soldered to bands placed on the mandibular first permanent

molars. Shortly after the use of intermaxillary elastics is begun, the necessary expansion of the mandibular arch is obtained by means of compound auxiliary springs soldered to the lingual arch wire, while alignment of the incisors is effected through ligatures and labial arch wire. During the time elastics are worn, even though the incisors are in alignment, ligatures must be used on anterior teeth to stabilize anchorage.

At this point in treatment, the patient is instructed in the pterygoid and masseter-temporal exercises as outlined by Rogers. Aside from the physiologic value of these exercises, there is a decided psychologic value as well. With the patient sharing in the responsibility of attaining a result, the whole procedure takes on an added importance and cooperation is generally improved.

As the maxillary and mandibular arches approach a normal mesiodistal relationship, if it becomes evident that rotation and axial inclination of the individual dental units cannot be effectively dealt with by the continued use of simple ligatures and labial arch wire, then the required number of bracketed attachment bands of preferably the edgewise or snap channel type are placed. With these and a suitable labial wire the necessary corrections are made, special attention being directed to the canines and first molars.

Using the above outlined procedure, it has been interesting to note that quite frequently in cases where treatment is instituted at 12 or 13 years of age, the correction of the mesiodistal relationship of the arches is simultaneously accompanied by an increase in dental height. It is needless to state that this automatic opening of the bite is highly desirable, for otherwise it becomes necessary to employ some form of mechanical bite plane to attain this end. Where a bite plane is indicated, it is used concurrently with the intermaxillary elastics and consists of a filigree wire bite plane incorporated in the maxillary lingual arch wire.

After the individual teeth and dental arches have been placed in a functional relationship, the last step in treatment, the period of retention, is begun. The corrective appliance in the maxillary arch is replaced with a Hawley type vulcanite bite plane, while that in the mandibular arch is replaced with a lingual arch wire soldered to bands placed on first premolars. The length of time that mechanical retention must be continued in Class II, Division 2 cases is individual in nature and largely dependent on the growth processes. Clinical experience has demonstrated that as a general rule where the maxillary incisors are in a vertical position, the case requires longer retention than where they are lingually inclined.

The prognosis of Division 2 cases is generally more favorable than that of Division 1. Little or no difficulty is encountered in maintaining the arches in the newly established mesiodistal relationship, and while in some cases there is a tendency for the bite to close, this, to a large extent, can be overcome by continued use of the maxillary retainer through the period of accelerated growth following adolescence.

That the foregoing discussion of the factors involved in the treatment of Class II, Division 2 malocclusion is far from adequate is appreciated, for it has only touched lightly on a few of the many problems related to these factors,

but, if in a measure, it has demonstrated the need of, as well as the advantage to be gained from, a correlation of them, the purpose of this paper has been realized.

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1338 KEITH BUILDING

CHANGING CONCEPTS IN DIAGNOSIS

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DURING the past four decades the profession of orthodontics, in seeking to understand every condition and circumstance of growth and development of the human denture, has accepted many changes in diagnostic methods. Every addition to orthodontic knowledge makes necessary some change in methods of diagnosis. The order of procedure may remain the same, but technique changes. New methods which were founded on scientific truths having a practical application have been adopted as rapidly as our comprehension will allow.

Peter Latham one hundred years ago said: "Whenever in medicine anything like a discovery has been made, anything which has had the show of a principal or a law, a large surrender of cherished opinions has always followed and knowledge has seemed to begin its career afresh from a new starting place."

To make correct diagnoses by which a rational plan of treatment may be pursued is one of the most sought-for attainments in the practice of orthodontics. The newer facts in orthodontics and the collateral sciences make diagnosis simpler and more accurate in some respects, but in others it becomes more difficult and complicated. Diagnosis presents problems that are quite different from those of even a decade ago, as many new facts are being established concerning orthodontic and clinical diagnosis.

In comprehending the complicated morphologic deviations met with, we have been greatly benefited by the addition of extraoral methods which have included our former intraoral conception in regional diagnosis. The facts supplied by collaborating with those interested in the growth of dental medicine have extended our field into clinical diagnosis. Diagnosis in orthodontics now has changed from a procedure as simple as examining the occlusion of the teeth to a very practical process dealing with growing human beings, many of whom are starting life with dental and facial deformities, perverted muscular function, malnutrition, and the threat of facing psychologic defeat before their battle is started.

"What is the matter with the patient?" is a question that has had to be answered daily since the time of Hippocrates.

The history of the development of diagnosis in medicine, sketched briefly, reveals that "Hippocrates (460 to 370 B.C.) 2,300 years ago, his only armamentarium a keen perception of what may be seen and felt, described diseases so accurately that from his classification many of them may be recognized today."[1]

"He studied the patient minutely and recorded accurately the results of his inspection. No detail was too trivial to escape him."[2]

"He required written description of all patients' symptoms and a correct model of the diseased part made of wax, marble, ivory or precious metal—according to the patient's wealth."[3]

It is interesting to note that following Hippocrates, Galen (A.D. 131 to 201), a famous physician, studied hard and wrote voluminously but, unlike the dispassionate Hippocrates, "he made every effort to prove his theories correct. The person who differed from him was his enemy. He attempted dogmatically to settle every question forever."

"During the Dark Ages following, the world was ruled by fear and superstition in which any evidence of original thinking was sternly suppressed and promptly and savagely punished."[3]

Among a few who contributed were Orebasius of Gartus (A.D. 325 to 403), who discovered the salivary glands, and Altius of Amids (A.D. sixth century), physician to Emperor Justuvian, who left the best descriptions of the diseases of the eye, ear, nose, throat, and teeth.

After 2,100 years Auenbrugger (1722 to 1809) invented percussion as a means of diagnosis, and fifty years later, in 1816, Laennec (1781 to 1826) invented the stethescope. "Because of the fatness of a patient he made use of an acoustic principle, using a roll of paper, later constructing cylinders of parchment. Still later a wood device 1½ inches in diameter with a ¼-inch core and 1 foot in length was used.

"It is only in the past fifty years that medicine has added the assistance given by the modern sciences: chemistry, bacteriology, electricity, and the roentgen ray. Thus through the centuries has been evolved the science and art of medical diagnosis."[3]

McCoy[4] writes that, "We should not fall into the error of attempting to segregate our special field from the rest of the body, for the study of growth and development in all its phases is necessary to a correct comprehension of some of our most important problems.

"No perfect plan of diagnosis has as yet been developed, nor is it probable we will ever see the day when such a happy circumstance will be realized. Human judgment, rarely infallible, must of necessity be called upon to some extent to interpret what we see in our cases, and it is, therefore, of vital importance that we approach the question supplied with every helpful means at our command to sharpen our powers of observation and guide our diagnostic acumen."

Since orthodontics is a part of the vast field of medicine which deals with all the sciences of life, we must not fail to comprehend, at least in part, the ever-broadening scope of orthodontic diagnosis. It appears as a continual challenge to our ability to absorb new facts, to accept new truths and to give them their merited place in daily practice. Facts to be of value must be observed in their relations to other facts and truths lie in these relations.

The first American texts on orthodontics consisted of one published in 1880 by Dr. Norman Kingsley entitled *Oral Deformities* and another in 1888 by Dr. J. N. Farrar entitled *Irregularities of the Teeth.* From this time until the early part of the twentieth century no diagnostic classification of maloc-

clusions was introduced. Farrar's two-volume work was said to have been epoch making (Pfaff),[5] and Kingsley's work embraced several chapters on malocclusion of the teeth, their etiology, diagnosis.

When Dr. E. H. Angle[6] published *Malocclusion of the Teeth* in 1898, he introduced a classification of malocclusion based on the law of the first molars, the keys to occlusion. This may be said to have inaugurated the specialty of orthodontics.

He rightly contended that "some writers of the old school . . . ., basing classification upon superficial symptoms instead of fundamental principles, have arranged cases in classes variously named for one or other conspicuous symptoms such as 'open-bite', 'saddle-shaped arch', 'v-shaped arch', 'narrowed upper arch on one side', 'narrowed upper arch on both sides', 'prominent canines', 'inlocked laterals', 'protruding upper incisors', 'retruding lower incisors', and others. But such classifications are erroneous and doubtless arose from a superficial study of one or the other of the dental arches without due consideration of their relations or of the dental apparatus as a whole from the basis of normal occlusion."

He conceived that the normally occluded denture should have a definite relationship to the head, for in the well-known paragraph on the "Line of Occlusion," he said, "that as the dental apparatus is only a part of the great structure, the human body, each part and organ of which was fashioned according to the line of design, it must have been intended that the line of occlusion should be in harmony in form and position with, and in proper relation to, all other parts of the great structure."

His classification organized all cases of malocclusion into three great classes with divisions and subdivisions, based on the mesiodistal relations of the teeth, dental arches, and jaws, depending on the mesiodistal position of the first permanent molars in occlusion. Naming these classes was based on a numerical terminology. This well-known and invaluable contribution was the first blow struck at the chaotic condition in orthodontic diagnosis, or so-called diagnosis of malocclusion.

A later text by Case in 1908, entitled *Dental Orthopedia,* disclosed the use of facial as well as dental casts as an aid in diagnosis. He divided the dentofacial area into four "zones of movement" by drawing four transverse lines, each starting from points within the changeable area, and dwelt at length on facial diagnosis.

In 1912, *Orthodontics,* published by Dr. B. E. Lischer,[7] defined diagnosis as follows: "Broadly interpreted, every diagnosis implies a consideration of several general conditions, e.g., the age, general and oral health of the individual, the relative degree of growth and development, the recognition of causative factors, etc. Custom in orthodontic practice limits its use and embraces: (a) the distinguishing of one form of malocclusion from another; (b) the detection of anomalies of dentition and of the jaws and related structures other than those of form and position; and (c) the degree of facial deformity associated therewith."

As aids to diagnosis he made use of the voluntary forward bite of the patient for study of his profile, originated the insertion in the mouth of wax contours to note the probable effect of a treatment, and employed photographs extensively. In studying the form of the head he developed a radiometer to be used in anthropometry. A chapter on "Normal Variation of the Head Form" showed the attention anthropologists have given to the relationship of the teeth, their osseous base, and profile lines of man.

Other contributions associated with diagnosis brought forth in this text were the diagnostic terms, neutroclusion, mesioclusion and distoclusion which were adopted at a later date by the American Society of Orthodontists. This terminology was based on a consideration of arch relations.

Lischer also first used the now well-known terms, labioversion, linguoversion, and torsoversion to designate malposition of the individual teeth. He suggested that the term gnathia (meaning jaw), which had been used extensively in medical literature, be used to differentiate malformation of the jaws, i.e., overdevelopments to be known as macrognathism, and arrested developments as micrognathism.

Dr. A. P. Rogers[8] in 1917 read the first of a series of papers dealing with myofunctional therapy based upon the principle of modification of form by function. This fine contribution to therapy was also a direct contribution to the science of diagnosis. The recognition of the importance of facial posture and appraisal of the muscular elements of the face, their atrophy and disuse were an essential part of any diagnostic procedure.

It is apparent that diagnostic procedure to date has been predominantly through intraoral methods with efforts being made to enlarge the understanding of dental and facial anomalies.

New facts and generalizations were constantly being added, and in 1926 a book written by Simon,[9] *Diagnosis of Dental Anomalies,* translated by Lischer, introduced a correlated method of relating the denture to the head. Thus, it was seen that the attempts to combine intraoral and extraoral diagnosis were nearer accomplishment.

The gnathostatic method presented by Simon found many orthodontists in this country ready to adopt it. This cephalometric method, which includes the occlusal classification, gave a differential diagnosis based on the condition of the denture under construction and on (a) deviations of individual teeth, (b) deviations of the entire denture in relation to the head, (c) deviations of facial features and jaws and (d) made finer differentiations in considering the denture in relation to height, width and length. The only thing constant in this method was that the orbital and medial planes were at right angles to the horizontal plane.

The points and planes of the head used in gnathostatics were of anthropologic origin. For the first time in regional orthodontic diagnosis it was now possible to locate points which were not in the immediate changeable area.

Lowy,[10] in a paper on diagnosis, stated, "If a line is drawn by itself how can anyone determine whether it is vertical or horizontal unless its position in space is related to something on the same plane? To make a comparison

one must have something to compare, and if the denture was to have been considered an anatomic and physiologic part of the head, an exact connection with the skull must be obtained."

McCoy[4] stated in *Applied Orthodontics:* "With this broader concept before us, the limitations of our old methods of intraoral diagnosis immediately become apparent. They cannot be logically applied even if the denture only is to be considered, for it is not an isolated object, but one with many dependent relationships."

Orton and Lischer[11] in a survey of 2,982 university students found 132 anatomically correct unmutilated dentures. Fifty-two of these dentures were recorded by the gnathostatic method. They concluded that "this survey has forced on our convictions the utter inadequacy of diagnosing occlusal relationships by direct observation of the teeth or by use of a so-called study model. The superiority of the gnathostatic method as a diagnostic guide has been clearly demonstrated."

Many criticisms of the philosophic treatise presented with this method were forthcoming; a few were well conceived, others founded on misinterpretations.

At the present time further progress in the study of dentocranial relations is being made through the use of profile roentgenographs.

Deductions and conclusions of the excellent work being carried on by Broadbent and others are contained in recent reports by Higley and Speidel[12] and by Brodie, Downs, Goldstein and Myer.[13] Fisk,[14] DeCoster,[15] and Korkhaus[16] have written of the use of this method of cephalometric roentgenography for orthodontic diagnosis and as a means of demonstrating the results of orthodontic therapy.

Undoubtedly the methods of regional or topographic diagnosis will continue to expand as rapidly as we are able to absorb and coordinate new facts. However, the demands of the rapidly growing field of dental medicine require that we have more accurate knowledge of clinical and pathologic diagnosis.

A most outstanding contribution of recent years was made by Becks in extending our knowledge of diagnosing pathologic bone changes, particularly those accompanying root resorptive processes.

The proper diagnosing of radiographic pictures is dependent on a broad understanding of the physiology and pathology of bone life. Two lesions often overlooked are osseous dystrophy, which is characterized by a hypoplastic function of osteoblasts and an inferior quality of the bone-forming cells, and osteoporosis, a condition whereby the marrow spaces of alveolar bone are enlarged through resorption by osteoclasts and are filled with fat marrow.

In the *Symposium on Bone* Becks[17] states, in speaking of the various types of atrophy: "I am inclined to say that every practitioner should have a more or less complete understanding of the microscopic picture of these pathologic changes in bone which are invisible to the naked eye."

It would then be possible in diagnosing radiographs to visualize the osteoblasts and osteoclasts at work, and our diagnostic findings would eventually lead us to recognize even the mitigated forms of bone pathology.

Bone pathology is so closely allied to the endocrines and nutrition that a failure to follow advances along these lines places the orthodontist at a disadvantage. It is becoming increasingly necessary to observe evidences of bone pathology and have the ability to discover some forms of endocrine disturbance in their incipiency, when present.

The orthodontist in many instances is in more frequent contact with the developing child than his pediatrician or family physician. When indicated, it is axiomatic that patients with such symptoms be referred to the most competent physicians in this field for completion of diagnosis and therapy. One who is truly competent in diagnosis will consider these possibilities as part of a routine procedure.

Socrates said: "I dare say you have heard eminent physicians say to a patient who comes to them with bad eyes, that they cannot treat the eyes by themselves, but that if the eyes are to be cured, the head must be treated. And then again they say that to think of the head alone, and not of the rest of the body also, is the height of folly. And arguing thus they apply their methods to the whole body, and try and treat and heal the whole and the part together."

And so today we should no longer think of ourselves as being adrift from the benefits that may accrue from being an integral part of medical science.

The field of nutrition during the past decade has afforded the orthodontist, who considers clinical diagnosis important, many opportunities to enrich his store of knowledge. Nutrition is well on its way to form a most positive and practical connecting link in all branches of medical science.

Dr. Nina Simmonds,[18] in a recent paper, said that from a nutrition standpoint, there is a possibility a child may be a good or poor orthodontic risk and that a satisfactory diet prior to, during, and after treatment may be highly important in bringing it to a satisfactory close. She says that just as heredity and nutrition are the first factors considered in animal industry, so should they be in human problems.

Since 1934 Dr. Simmonds has made studies of the nutrition set-up on all children accepted for orthodontic treatment at the University of California College of Dentistry. In explaining the meaning of "nutrition set-up" she says: "Please notice that I do not say 'dietary set-up.' 'Nutrition set-up' is a phrase I have adopted which includes more than the food a person has eaten. It attempts to portray the general health, the home set-up as well as the nutrition of an individual."

Her classification of these children from this standpoint divides them into four classes, i.e., very poor risks, poor risks, fair risks, and good risks. This classification may prove very useful when diagnosis of malnutrition is included in our methods.

The conclusions based on studies of the first eighty cases just mentioned disclosed that 3.75 per cent were listed as very poor risks; 23.75 per cent as poor risks; 51.25 per cent as fair risks, and only 21.25 per cent as good risks.

Regardless of whether or not these appalling data hold true in private practice in all sections of the country, this study is sufficiently illuminating to command our instant attention. To evaluate the nutrition set-up of a child

and determine the type of risk the child may be, in the author's opinion, should be a definite part of diagnosis in orthodontics.

Rogers[19] stated: "It is important that the orthodontist give more attention to the study of nutritional deficiencies. While thus far his training does not qualify him to prescribe diets indiscriminately, because this can be safely done only by the skilled physician who has at his command every facility to determine the nutritional requirements of the individual child, the orthodontist even in view of this fact should be competent to diagnose malnutrition as he meets it among his patients; and, when he does, he should have the forethought to refer the child to a competent physician for a thorough scientific examination and treatment. His full duty as an orthodontist is not performed unless he so conducts himself."

In summing up, it must be remembered that the interests of the patient are paramount.

I cannot pretend to have offered more than a small part of the developments of medicine and the corollary sciences which are changing our methods of diagnosis. Orthodontic diagnosis seems to be emerging from a state of turmoil with many problems yet unsolved. The solution of some of these may be greatly clarified by continuing the close cooperation between practitioners and research workers. The contributions of Simmonds and Becks are examples. Leaders in thought in the medical and dental professions are seeking aid from other sciences as well as from one another in solving their problems.

Since the whole bodily structure is united by delicate strands of nerve tissue and countless blood vessels, we cannot expect the inroads of disease to affect one part only. The term diagnosis means more than merely labeling a morphologic deviation of the denture. It implies the use of more knowledge than one person can acquire, and we must have the help of pediatricians, internists, laboratory investigators, and other qualified specialists.

Orthodontic and medical knowledge is in a state of flux. As long as readjustments are necessary in our ideas of diagnosis, we will continue to progress.

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COBB BUILDING

CONSIDERATIONS ON THE MECHANICS OF THE PIN AND TUBE APPLIANCE

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THE pin and tube appliance is derived from the "working retainer" of Angle. The purpose of the working retainer was to straighten up the front teeth after their crowns had been tipped into the line of occlusion. The pin and tube appliance, on the other hand, moves the front teeth bodily. In this paper, I will describe, first, the conditions necessary to obtain the desired efficiency of this appliance, second, the direction of force on the molar anchorage, and third, additional aids in strengthening the molar resistance.

A. The working retainer[1, 2] consists of a three-sectional arch, i.e., a middle section and two end sections. On the middle section are soldered pins which fit into delicate tubes soldered to bands on the anterior teeth. The pins are more nearly vertical to the plane of the arch than the tubes (Fig. 1 *a*). When the pins are inserted into the tubes, the distal ends of the labial arch lie occlusally to the horizontal sheaths on the anchor bands (Fig. 1 *b*). When the ends are pushed into the sheaths, the arch is under an elastic tension. This tension may be expended in various ways: First, by the desired correction of the incisor roots. In this case, we must assume that the molars remain in their original positions. Second, by elongation of the molars. For this to happen, the incisors must be stationary. Or finally, by a combination of these movements. If precious metal wire is used, permanent distortion of the arch is negligible, and so I have not taken it into account.

The direction of the pressure on the anchor teeth can be determined in accordance with Fig. 1 *b*. When the arch lies passive in the molar sheaths, the pins form the angle β with the tubes. Because the pin is firmly soldered to the arch, the angle (marked $\propto$) formed by the pin and the plane of the arch is constant.

As all our calculations are made by projecting the appliance into the sagittal plane, only the "altitude of the arch" is important. In the Fig. 1, "*a*" is the altitude of the arch. This can be determined from its real longitude and breadth if its shape is geometrical, i.e., half-circle, half-elipse or parabola.

The passive relation of the arch, when the pins are not inserted into the tubes, is indicated at "*I*" (Fig. 1 *b*). After the pins are inserted, the position of the passive arch is indicated by "*II*"; its ends lie occlusally to the molars. Lines *I* and *II* form an angle, also labeled β. If the arch is fixed in the anterior tubes and in the molar sheaths, the only way it could reach a position of rest at line *II* would be for the molar to pass from *M* to *M'* (Fig. 1 *b*), through the segment of a circle with the radius "*a*." This is the real altitude of the arch, though it seems to be the longitude. The extent of orthodontic displacement in this instance is generally quite small, hence we may use the chord of the circle instead of the segment in these studies. The direction of the pull on the

anchor teeth is determined by the direction of this cord. It forms the angle $\sqrt{Q}$

$$\rho = \frac{180 - \beta}{2}.$$

As the angle β is generally very small, the angle ρ is hardly less than 90° and the force on the molar anchorage is directed occlusally, perpendicular to the plane of the arch; but this limit (i.e., 90°) cannot be attained if the apparatus is active.

B. The pin and tube appliance, which I will show, differs from the working retainer in that the pins and delicate tubes on anterior teeth are both set at the same angle to the plane of the arch wire; hence, the arch can be pushed into the molar sheaths and the anterior tubes at the same time and remain passive. The pin and tube appliance as originally invented by Angle[2] also has a three-sectional arch. The different parts are united by square pegs fitting into closely telescoping sleeves. Force is put into the arch by tightening nuts in front of the sheaths. A one-piece arch may be used if it is attached to the anchor bands by vertical tubes or locks, as suggested by Young.[18] A vertical loop is used in this method, and the arch is tightened by opening the loop. A number of modifications are described in the textbook of Korkhaus.[7] Oppenheim's modification, described by Petrik,[13] also uses nuts.

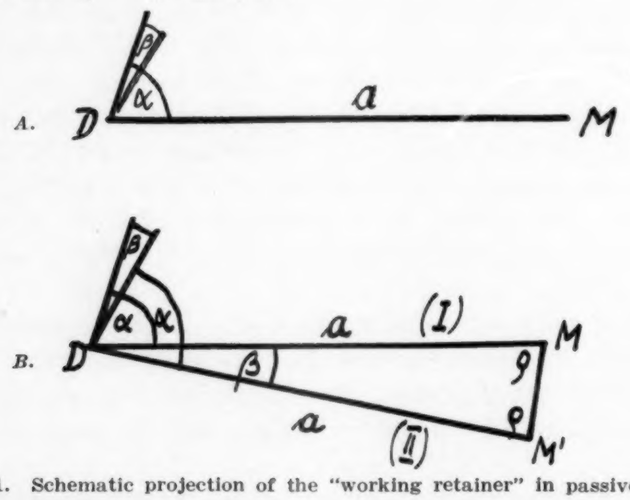


Fig. 1.—*A*. Schematic projection of the "working retainer" in passive state to a sagittal plane.

"*a*" is the altitude of the arch, α the angle between the plane of the arch and the vertical pin, β the deviation of the pin from the direction of the delicate tube; *M*: attachment of the arch on the molar, *D*: engagement of the arch on the incisor and fulcrum for the straightening of the root.

B. Load on the molar by the "working retainer." Sign as in Fig. 1*a*. Passive position of the arch, whereby vertical pins are not embraced by delicate tubes is marked with (*I*); the passive position of the arch after embracing the vertical pins in the delicate tubes, whereby the distal end of the arch stands off from the molar tube is marked by (*II*). *M* on the arch *I* corresponds to *M'* on the arch *II*.

The schematic projection of the appliance on a sagittal plane is shown in Fig. 2. The passive position of the arch is marked "*I*"; the union of pin and arch "K_1"; the attachment of the arch to the molar "M_1." It is intended that the appliance shall produce a bodily movement, i.e., that the incisal edge and the apex shall move an equal amount in the same direction. But it is easier to tip incisors than to move them bodily.

Let us suppose that the incisor was tipped labially. The center of rotation should be in "*D*" (Fig. 2). The determination of the true position of this center

has been the object of numerous investigations (Oppenheim,[9-11] Kranz and Falck,[8] Schwarz,[14-16] Klein,[6] Bauer and Lang[3]). None of these opinions has received universal acceptance. It is readily admitted there is a possibility that this center may be determined. Therefore, we will assume that the distance $\overline{DK_1}$ is known.

As the arch and pin are soldered, the angle α formed by $\overline{DK_1}$ and $\overline{K_1M_1}$ is constant and can be measured or calculated.

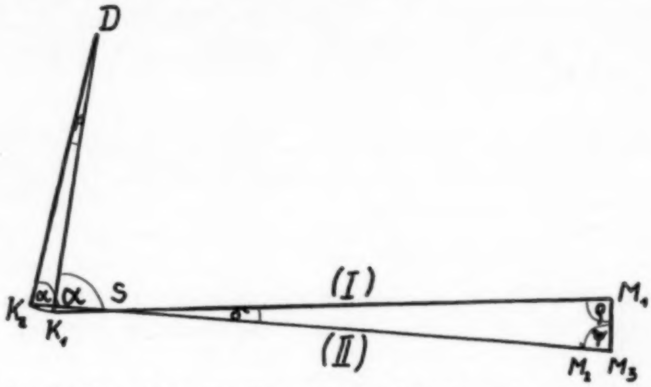


Fig. 2.—Determination of the direction of the load to the molar on the schematic projection of the pin and tube appliance to a sagittal plane. Original passive situation of the arch is marked with (*I*); attachment of the arch on the incisor is marked with K_1, on the molar with M_1. Center of rotation (at tipping of the incisors) is in *D*. The angle formed by $\overrightarrow{DK_1}$ and $\overrightarrow{K_1M_1}$ is α.

The incisor will be tipped by the angle β. To this altered position of the incisor the corresponding arch in passive state is marked with (*II*); it engages the incisor in K_2. To M_1 on the arch (*I*) corresponds M_2 on the arch (*II*). The device was tightened by elongation of the arch by the measure $\overrightarrow{K_1K_2}$; hence the arch engages the anchor molar not in M_2, but in M_3.

Arch (*I*) and arch (*II*) are crossing each other in *S* and form the angle σ.

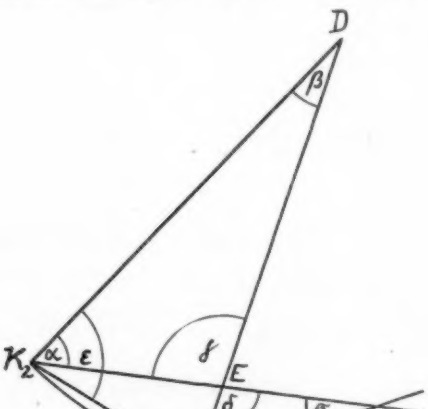


Fig. 3.—Auxiliary construction for the determination of the angle σ. Signs as in Fig. 2.

If we tip the incisor forward with *D* as the point of rotation, the angle β is formed (Fig. 2) and point K_1 is moved to K_2. The arch wire takes the position indicated by *II;* its original position is indicated by *I*. Lines *I* and *II* cross at *S* and form the angle σ. M_1 on the line *I* corresponds to M_2 on the line *II*. These movements are produced by elongation of the arch wire. The amount of this elongation is the distance traveled by K_1. K_1 moves along the segment of

a circle whose radius is $\overline{DK_1}$, and over small distances this segment is practically equal to its chord, the straight line $\overline{K_1K_2}$. We now measure this line and add it to the length of line *II* distally from M_2. The new end is marked M_3. $\overline{M_2M_3} = \overline{K_1K_2}$. The attachment of arch *II* to the anchor tooth is at M_3. When the incisor has been tipped through the angle β, the molar should be at M_3, passing through an undefinable curve. The chord $\overline{M_1M_3}$ is hardly different from the curve itself. Therefore, this chord, the straight line $\overline{M_1M_3}$, will be used to determine the direction of the pull on the molars. The angle ρ formed by the lines $\overline{K_1M_1}$ and $\overline{M_1M_3}$ should be calculated. For this, an auxiliary diagram (Fig. 3) is necessary.

1. In the isosceles triangle K_2DK_1, the equal sides and the angle β formed by them are known (Fig. 3). *These sides will hereafter be simply marked* $\overline{DK}$. The other angles (marked ϵ in the diagram) can easily be calculated:

$$\epsilon = 90 - \frac{\beta}{2} \qquad \text{(First equation)}$$

The unknown side $\overline{K_1K_2}$ can be determined according to the theory of sines:
$\overline{K_1K_2} : \overline{DK} = \sin\beta : \sin\epsilon$; or in consideration of the foregoing equation:

$$\overline{K_1K_2} = \overline{DK}\,\frac{\sin\beta}{\cos\beta/2} \qquad \text{(Second equation)}$$

As previously explained, $\overline{K_1K_2}$ is approximately equal to the elongation of the arch produced by tightening the appliance.*

2. In the auxiliary triangle K_1ES (Fig. 3) two angles are equal to corresponding angles of the triangle K_2DE ($\alpha = \alpha$ resp. $\gamma = \delta$); hence the third angle $\sigma = \beta$.

The angle formed by lines *I* and *II* is thus determined and equals angle β.

3. As a result of the foregoing calculations, all three angles ($\sigma = \beta$; $\epsilon - \alpha$; $\epsilon + \alpha$) and the side $\overline{K_1K_2}$ of the triangle K_1K_2S are known. The unknown sides can be determined very simply by the theory of sines.

$$\overline{K_2S} : \overline{K_1K_2} = \sin(\epsilon + \alpha) : \sin\beta$$

$$\overline{K_2S} = \frac{\sin(\epsilon + \alpha)}{\sin\beta}\overline{K_1K_2}.$$

In consideration of the first equation

$$\epsilon + \alpha = 90 - \frac{\beta}{2} + \alpha \text{ and}$$

$\sin(\epsilon + \alpha) = \cos\left(\frac{\beta}{2} - \alpha\right)$. This and the value for $\overline{K_1K_2}$ determined in the second equation shall be substituted in the formula of $\overline{K_2S}$:

$$\overline{K_2S} = \frac{\cos(\beta/2 - \alpha)\sin\beta}{\sin\beta\cos\beta/2}\,\overline{DK}, \text{ resp.}$$

$$\overline{K_2S} = \frac{\cos(\beta/2 - \alpha)}{\cos\beta/2}\,\overline{DK} \qquad \text{(third equation),}$$

or by elimination of the fraction:

$$\overline{K_2S} = \frac{\cos\beta/2\cos\alpha + \sin\beta/2\sin\alpha}{\cos\beta/2}\,\overline{DK}, \text{ resp.}$$

$$\overline{K_2S} = (\cos\alpha + \operatorname{tg}\beta/2\sin\alpha)\,\overline{DK} \quad \text{(third equation in other form).}$$

The side $\overline{K_1S}$ can be calculated in the same manner:

$$\overline{K_1S} : \overline{K_1K_2} = \sin(\epsilon - \alpha) : \sin\beta;$$

$$\overline{K_1S} = \frac{\sin(\epsilon - \alpha)}{\sin\beta}\,\overline{K_1K_2}.$$

*In this way, it should be possible theoretically to determine the real location of the point of rotation. The real elongation of the arch and the inclination of the moved incisor should be measured before tightening of the appliance and after the force has been expended. These measurements should be projected into a sagittal plane. But because of the inaccuracy of such measurements, this would be a wasted effort.

According to the first equation
$\epsilon - \alpha = 90 - \beta/2 - \alpha$ and
$\sin(\epsilon - \alpha) = \cos(\beta/2 + \alpha)$. This and the value of $\overline{K_1K_2}$ determined in the second equation will be substituted:

$$\overline{K_1S} = \frac{\cos(\alpha + \beta/2)\sin\beta}{\sin\beta\cos\beta/2}\ \overline{DK}, \text{ resp.}$$

$$\overline{K_1S} = \frac{\cos(\alpha + \beta/2)}{\cos\beta/2}\ \overline{DK}, \text{ or by elimination of the fraction:}$$

$$\overline{K_1S} = (\cos\alpha - \sin\alpha\ \mathrm{tg}\ \beta/2)\ \overline{DK} \qquad \text{(fourth equation)}$$

4. In the triangle SM_1M_2 (Fig. 2) the angle σ is known ($\sigma = \beta$); the sides $\overline{SM_1}$ resp. $\overline{SM_2}$ can be determined in consideration of the foregoing calculations and of the fact that $\overline{K_2M_2} = \overline{K_1M_1}$.

$\overline{SM_1} = \overline{K_1M_1} - \overline{K_1S}$ resp.
$\overline{SM_1} = \overline{K_1M_1} - \overline{DK}(\cos\alpha - \sin\alpha\ \mathrm{tg}\ \beta/2)$ (fifth equation)
and in the same manner:
$\overline{SM_2} = \overline{K_2M_2} + \overline{M_2M_2} - \overline{K_2S}$, resp. in consideration of the foregoing explanations:
$\overline{SM_2} = \overline{K_1M_1} + \overline{K_1K_2} - \overline{K_2S}$, or

$$\overline{SM_2} = \overline{K_1M_1} + \overline{DK}\ \frac{\sin\beta}{\cos\beta/2} - \overline{DK}(\cos\alpha + \sin\alpha\ \mathrm{tg}\ \beta/2) \quad \text{(sixth equation)}$$

The unknown angles of this triangle are marked ρ and ψ;

$$\frac{\rho + \psi}{2} = 90 - \beta/2 \qquad \text{(seventh equation)}$$

According to the tangent-thesis:

$$\mathrm{tg}\ \frac{\rho - \psi}{2} = \frac{\overline{SM_2} - \overline{SM_1}}{\overline{SM_2} + \overline{SM_1}}\ \cot\beta/2$$

$\overline{SM_2}$ and $\overline{SM_1}$ shall be expressed by values of the fifth and sixth equations:

$$\overline{SM_2} - \overline{SM_1} = \overline{K_1M_1} + \overline{DK}\ \frac{\sin\beta}{\cos\beta/2} - \overline{DK}\cos\alpha - \overline{DK}\sin\alpha\ \mathrm{tg}\ \beta/2 - \overline{K_1M_1} +$$
$$+ \overline{DK}\cos\alpha - \overline{DK}\sin\alpha\ \mathrm{tg}\ \beta/2, \text{ resp.}$$

$$\overline{SM_2} - \overline{SM_1} = \overline{DK}\ \frac{\sin\beta}{\cos\beta/2} - 2\ \overline{DK}\sin\alpha\ \mathrm{tg}\ \beta/2 \text{ and}$$

$$\overline{SM_2} + \overline{SM_1} = \overline{K_1M_1} + \overline{DK}\ \frac{\sin\beta}{\cos\beta/2} - \overline{DK}\cos\alpha - \overline{DK}\sin\alpha\ \mathrm{tg}\ \beta/2 + \overline{K_1M_1} - \overline{DK}\cos\alpha +$$
$$+ \overline{DK}\sin\alpha\ \mathrm{tg}\ \beta/2, \text{ resp.}$$

$$\overline{SM_2} + \overline{SM_1} = 2\ \overline{K_1M_1} + \overline{DK}\ \frac{\sin\beta}{\cos\beta/2} - 2\ \overline{DK}\cos\alpha.$$

In consideration of these calculations:

$$\mathrm{tg}\ \frac{\rho - \psi}{2} = \frac{\overline{DK}\left(\frac{\sin\beta}{\cos\beta/2} - 2\sin\alpha\ \mathrm{tg}\ \beta/2\right)}{2\ \overline{K_1M_1} + \overline{DK}\left(\frac{\sin\beta}{\cos\beta/2} - 2\cos\alpha\right)}\ \cot\beta/2$$

$$\mathrm{tg}\ \frac{\rho - \psi}{2} = \frac{\overline{DK}\left(\frac{\sin\beta}{\sin\beta/2} - 2\sin\alpha\right)}{2\ \overline{K_1M_1} + \overline{DK}\left(\frac{\sin\beta}{\cos\beta/2} - 2\cos\alpha\right)} \quad \text{(eighth equation)}$$

ρ and ψ will be calculated according to the seventh and eighth equations:

$$\rho = \frac{\rho + \psi}{2} + \frac{\rho - \psi}{2} \text{ resp. } \psi = \frac{\rho + \psi}{2} - \frac{\rho - \psi}{2}$$

5. According to the foregoing deductions ρ shall be determined in a voluntarily chosen practical example.

$\overline{K_1M_1}$	$= 32$ mm.	log 32	$= 1{,}50515$
$\overline{DK}$	$= 16$ mm.	log 16	$= 1{,}20412$

$\alpha = 80°$	log sin 80° = 9,99335 –10
	log cos 80° = 9,23967 –10
$\beta = 5°$	log sin 5° = 8,94030 –10
	log sin 2°30′ = 8,64968 –10
	log cos 2°30′ = 9,99959 –10

num	log
$\sin\beta$	8,94030 –10
$-\sin\beta/2$	–8,63968 +10
1,998	0,30062

$$\frac{\sin\beta}{\sin\beta/2} = \log\sin\beta - \log\sin\beta/2$$
$$= 1{,}998$$

num	log
2	0,30103
$\sin\alpha$	9,99935 –10
1,970	0,29438

$$2\sin\alpha = \log 2 + \log\sin\alpha$$
$$= 1{,}970$$

$$\frac{\sin\beta}{\sin\beta/2} - 2\sin\alpha = 0{,}028$$

$$\overline{DK}\left(\frac{\sin\beta}{\sin\beta/2} - 2\sin\alpha\right) = \log 16 + \log 0{,}028$$

num	log
16	1,20412
0,028	0,44716 – 2
0,4480	0,65128 – 1

$$= 0{,}448$$

$$2\,\overline{K_1M_1} = 64$$

num	log
$\sin\beta$	8,94030 –10
$-\cos\beta/2$	–9,99959 +10
0,087	0,94071 – 2

$$\frac{\sin\beta}{\cos\beta/2} = \log\sin\beta - \log\cos\beta/2$$
$$= 0{,}087$$

num	log
2	0,30103
$\cos\alpha$	9,23967 –10
0,347	0,54070 – 1

$$2\cos\alpha = \log 2 + \log\cos\alpha$$
$$= 0{,}347$$

$$\frac{\sin\beta}{\cos\beta/2} - 2\cos\alpha = -0{,}26$$

$$\overline{DK}\left(\frac{\sin\beta}{\cos\beta/2} - 2\cos\alpha\right) = \log 16 + \log(-0{,}26)$$

num	log
16	1,20412
0,26	0,41497 – 1
4,16	0,61909

$$= -4{,}16$$

$$2\,\overline{K_1M_1} + \overline{DK}\left(\frac{\sin\beta}{\cos\beta/2} - 2\cos\alpha\right) = 59{,}84$$

num	log
0,448	0,65128 – 1
–59,840	–1,77699
0,0075	0,87429 – 3

$$\mathrm{tg}\,\frac{\rho-\psi}{2} = \frac{0{,}448}{59{,}840}$$
$$= 0{,}0075$$

$$\frac{\rho-\psi}{2} = 0°\ 26'$$

$$\frac{\rho+\psi}{2} = 90° - \beta/2$$

$$\frac{\rho+\psi}{2} = 87°\ 30'$$

$$\rho = 87°\ 56'$$
$$\psi = 87°\ 04'$$

C. Angle's original appliance consisted of a three-part arch with threaded end sections. It was fastened to the anchor bands by the ordinary horizontal sheaths. However, the adjustment of the divided arch was difficult and required high technical skill. Therefore, Young[18] modified the manner of attaching the appliance to the molars. He fastened the arch to the molar bands by

vertical tubes. Using such locks, the entire arch may be inserted as a unit since all guides are parallel. The direction of insertion is occlusogingivally.

As is well known, vertical posts slide out of vertical molar tubes easily and often. This is because of the tendency of the distal ends of the arch to move occlusally. If it is our aim to displace the incisors bodily, profiting the anchorage of the molars, the arch must be securely fastened in the vertical molar tubes (Petrik[13]). This makes the intraoral adjustment of the appliance difficult. The use of the sectional arch and its attachment by horizontal sheaths, therefore, seems to me to be easier and especially safer, because it is impossible for it to slide out of the molar tubes.

In this connection a plan of Burill[5] should be mentioned. He introduced the pin in the anterior tubes from gingival to occlusal. He mistakenly thought he could increase thereby the efficiency of the appliance. Pushing the pins into the vertical tubes from this direction, especially when an undivided arch is used, is difficult and uncomfortable. For all that, the advantage of not being forced to secure the distal ends of the arch would be in favor of this method.

D. If bodily movement of the incisors is to take place, we must assume that the anchor teeth will not become elongated. As long as the anchor teeth maintain their original positions, the incisors must be moved bodily. Conversely, if the incisors maintain their original positions, the molars will be displaced distally. Tipping of the incisors must induce elongation of the molars. Generally, stationary anchorage of the molars is desired.

Against these dislodging influences, the molars are assisted by natural means as well as by artificial measures. The distal movement of the molars is resisted by their distal neighbors or their germs. Their antagonists help prevent elongation, and the peridental fibres oppose displacement in both directions. In addition to these factors tending to hold the molars naturally in their places, there is one type of malocclusion which brings, besides the intruding forces of the occlusion, another pressure that tends to shorten the molars. This pressure has to be taken into consideration in treating lingually locked maxillary incisors. In attempting to bring them labially, the occlusion is disturbed. At each closure of the mouth, these moved incisors are pushed back toward their original positions by the mandibular front teeth. This interference tends to shorten the molars and hinders the tipping of the incisors. However, this resistance to elongation is only occasional for if the teeth are sore, the patient will move the mandible forward to avoid the pain at each closure of the mouth.

There are several methods of re-enforcing the molar anchorage. One is the well-known plan of extending a spur distally from the first molar to rest on another spur attached to a band on the second molar. In the same manner one can extend a spur mesially too. However, one can also use elastics successfully. These are stretched as in Class III between hooks on the anchor bands and an arch on the mandibular teeth, lying gingivally to the mandibular incisors. The tension on the maxillary molar, therefore, is mesial and occlusal.

The mesial component is desirable for it strengthens the anchor teeth against eventual distal shifting. But the occlusal component is absolutely contraindicated; the anchor teeth should be re-enforced against any lengthening. The occlusal component of the intermaxillary rubber augments the objectionable tendency and favors the tipping movement of the incisors.

However, the method we now prefer is to stretch elastics from the anchor bands horizontally to rods fastened vertically to a chin cap.*[12, 4] These rubber bands are worn only at night. The elastics work only horizontally, equalizing the distal pressure on the molars. If correctly placed, they have no elongation factor.

Let us now see if they can prevent elongation of the molars. The elastics should be fastened to the vertical rods so as to prevent them from sliding downward. If the anchor teeth should become elongated, the rubbers would acquire a vertical component, provided the position of the chin cap remains unchanged. But this is not the case, for with the elongation of the molars, an opening of the bite is brought about, thus carrying the chin and the chin cap to a lower level. So the elastics which originally pulled only horizontally will acquire a vertical component, and work occlusally to elongate the molars. Hence, it would seem advantageous to stretch the rubbers right from the start not horizontally but somewhat obliquely upward in front so as to give them a tendency to shorten the anchor teeth. This can be accomplished best by soldering the hooks on the molars as far occlusally as possible and placing the points of attachment on the rods as far cranially as possible. As these elastics have to pass between the lips generally closed at night, their vertical (shortening) component can be only very slight. To insure this objective and increase the efficiency of the shortening component, it would be advisable to use hooks as shown in Fig. 4.

Fig. 4.—Hooks on the anchor bands for the elastics, to be stretched to a "chin cap with vertical rods."

With the working retainer, conditions are more favorable for resistance to the elongation of the molars. Artificial re-enforcement of the anchor teeth is not necessary, for the molars are kept in their positions by the tendency of the tipped incisors to relapse. The tipped incisors tend to return to their former positions. This is possible only if the molars go distally and become shortened (Fig. 5). This tendency of the incisors to relapse supports the molars against their elongation during the change of the angle of inclination of the front teeth.

E. Finally, we will calculate the elongating forces acting on the molars, not their real values, but only their ratios in proportion to the forces acting on the incisors. For this calculation let us suppose that the incisor is tipped

*This use of the chin cap goes back to Gruenberg and Oppenheim.

by the force P. The direction of this force P in small displacements is the chord of the curve $\overline{K_1K_2}$ (see Figs. 3 and 6*b*). The center of rotation is in D. Hence the momentum of this force working on K_1 is $P.k$, where k is the arm of this force P, which can be determined according to Fig. 6*b:*

The force arm $k = \overline{DT}$. This stays perpendicular to the direction of the working force (represented by the line $\overline{K_1K_2}$). Thus the angle β of the isosceles triangle K_2DK_1 is bisected by $\overline{DT}$. So a rectangular triangle DTK_1 is formed, in which angle $\beta/_2$ and the side $\overline{DK}$ are known. From these figures $\overline{DT}$ can be calculated by the following equation:

$\overline{DT} = \overline{DK} \cos \beta/_2$.

The force working on the molars may be marked with Q. Its direction is the straight line $\overline{M_1M_3}$ (Fig. 6*a*). The arm of this power is marked "*h*"; "*h*" can be calculated according to Fig. 6*a:*

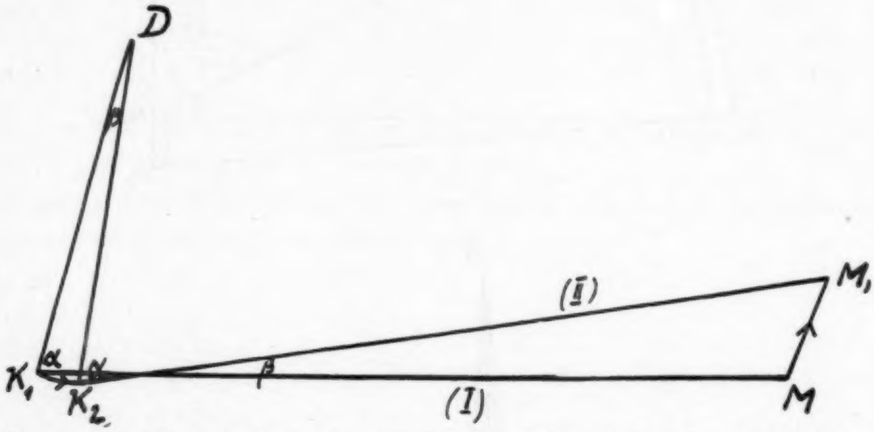


Fig. 5.—Altered load on the anchor teeth by the working retainer in consequence of relapse of the incisors. Signs as in Fig. 1*b*. (*I*): original passive state of the arch; (*II*): passive state after relapse of incisors.

1. In the triangle K_1DM_1, the sides $\overline{DK}$ and $\overline{K_1M_1}$ and the angle $\propto$ formed by them are known. The other angles (marked with γ resp. δ) may be determined by the following equations:

$$\frac{\gamma + \delta}{2} = 90 - \propto/2$$

$$\text{tg}\ \frac{\gamma - \delta}{2} = \frac{\overline{K_1M_1} - \overline{DK}}{\overline{K_1M_1} + \overline{DK}} \cot \propto/2.$$

For all later determinations, the two angles γ, δ may be assumed to be known.

In the same triangle the unknown side $\overline{DM_1}$ can be calculated by the theory of sines:

$\overline{DM_1} : \overline{K_1M_1} = \sin \propto : \sin \gamma$; and

$$\overline{DM_1} = \frac{\sin \propto}{\sin \gamma} \overline{K_1M_1}.$$

2. The power arm "*h*" is the unknown side $\overline{DR}$ in the triangle DRM_1 (Fig. 6*a*). In this triangle, the side $\overline{DM_1}$ which is the hypotenuse of the right triangle and the angle marked λ [$\lambda = 180 - (\rho + \delta)$] are known. From these data, $\overline{DR}$ can be calculated:

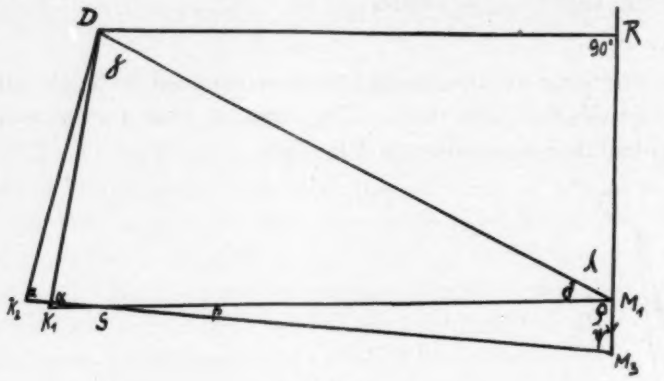
$\overline{DR} = \overline{DM_1} \sin \lambda$, resp. subsituted the above determined value of DM_1 and expression of λ by earlier calculated values:

$$\overline{DR} = \frac{\sin \propto \sin (\rho + \delta)}{\sin \gamma} \overline{K_1M_1}$$

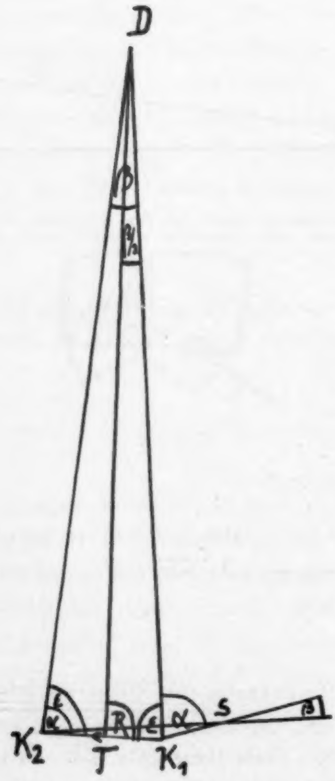
γ can be expressed by both other angles of the triangle K_1DM_1; hence, the above equation can be written also:

$$\overline{DE} = \frac{\sin \alpha \sin (\rho + \delta)}{\sin (\alpha + \delta)} \overline{K_1M_1}$$

These determinations of the arms of the working forces are valid only for small displacements and even then only approximately. **In reality, the direction of the force is never the chord of a curve, but its tangent. So the accurately calculated arm of the force P is not $\overline{DK} \cos \beta/_2$, but really $\overline{DK}$. The calcula-**



6A.



6B.

Fig. 6.—*a,* Determination of the arm of the power working on the molars. Direction of the power is marked with an arrow. For signs see the text. *b,* Determination of the arm of the power working on the incisors. Direction of the power is marked with an arrow. For signs see the text.

tions of the power arm of Q would be still more complicated. Therefore we must confine ourselves to the above approximate determinations.

Generally orthodontic movements of teeth take place at a very slow rate. Therefore for orthodontics the laws of statics rather than these of dynamics would apply, at least for the consideration of the efficiency of the different devices (Winkler[17]). The apparatus is generally in equilibrium, hence rotatory moments on each point of the arch must be equal. An equilibrium is:

$P.k = Q.h$, resp.

$Q = P \frac{k}{h}$, or substituting the foregoing calculated values of the arms of both powers:

$$Q = P \frac{\overline{DK} \cos \beta/2}{\overline{K_1M_1} \frac{\sin \alpha \sin (\rho + \delta)}{\sin (\alpha + \delta)}}, \text{ resp.}$$

$$= P \frac{\overline{DK}}{\overline{K_1M_1}} \cdot \frac{\cos \beta/2 \sin (\alpha + \delta)}{\sin \alpha \sin (\rho + \delta)}$$

The fraction, by which P has to be multiplied, is a true one, at least for measurement of orthodontic movements; hence $Q < P$.

In agreement with the foregoing deductions Q shall be calculated according to the practical example given above:

$$\frac{\gamma + \delta}{2} = 50^\circ$$

$$\text{tg} \frac{\gamma - \delta}{2} = \frac{\overline{K_1M_1} - \overline{DK}}{\overline{K_1M_1} + \overline{DK}} \cot \alpha/2$$

$$= \frac{16}{48} \cot 40^\circ$$

$$\frac{\gamma - \delta}{2} = 21^\circ\ 40'$$

$\gamma = 71^\circ\ 40'$ resp. $\delta = 28^\circ\ 20'$

According to these calculations:

$$Q = P \frac{16}{32} \frac{\cos 2^\circ\ 30' \sin 71^\circ\ 40'}{\sin 80^\circ \sin 70^\circ\ 14'}$$

$Q = 0{,}5113$ P

num	log
16	1,20412
cot 40°	10,07619 −10
	11,28031 −10
48	−1,68124
tg 21° 40′	9,59907 −10
cos 2° 30′	9,99959 −10
sin 71° 40′	9,97738 −10
16	1,20412
	1,18109
sin 80°	9,99335 −10
sin 70° 14′	9,97363 −10
32	1.50515
	1.47213
0,5113	0,70869 − 1

SUMMARY

The pin and tube appliance is suited for the bodily movement of incisors only as long as the molar teeth are not elongated. Tipping of the incisors must induce elongation of the molars. They should be re-enforced in their anchorage to prevent distal movement and elongation. This can be accomplished by stretching elastics from the anchor bands to a chin cap with vertical rods, and not by intermaxillary rubbers. These rubber bands should be ap-

plied in such a manner that a vertical shortening component will also be imparted to them.

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SKELETAL ANOMALIES ASSOCIATED WITH CLEFT PALATE AND HARELIP

Don C. Lyons, D.D.S., M.S., Ph.D., F.A.P.H.A., Jackson, Mich.

SKELETAL and tissue anomalies associated with cleft palate and harelip have occasionally been reported in dental literature, but only meagerly in ratio to their apparent occurrence. Beavis[1] found that a study of the cases passing through the University of Michigan clinic revealed that 19.8 per cent had some associated congenital defect. Many of these were slight and required careful examination to reveal their presence because they were of many types.

The following reported case of associated anomalies was rather unusual in all its ramifications. Baby R. B. (female) was born with a cleft palate, harelip, and a number of associated abnormalities of the extremities; namely, both polydactylism and syndactylism. No other defects could be found either upon clinical or post-mortem examination.

The immediate familial history is of especial importance from two angles. This case, in the first place, demonstrates a progressive development of strengthening of the genes of the parents, or one parent in particular. Baby R. B. was delivered at full term as the result of the third pregnancy of the mother, Mrs. A. J. B. The parents were young adults, the father 26 years of age and the mother 19. Her first conception resulting in pregnancy took place at the age of 15 years and 6 months by a man other than the father of Baby R. B. This fact is believed to be of importance in the case for it seems to eliminate the male side of the union as a possible factor in this history. This first pregnancy mentioned above resulted in a spontaneous abortion at the fifth month.

Mrs. A. J. B.'s second pregnancy, following her marriage with the father of Baby R. B., came to full term, but the fetus was a monstrosity delivered stillborn. The third pregnancy resulted in Baby R. B., and a subsequent fourth pregnancy fifteen months after the third, delivered a fully formed and apparently normal child, Baby J. B. (male). There was a slight notch in the tip of the uvula and a possible muscle fiber weakness in the right side of the upper lip of this child. It must be admitted, however, they were so slight that, if abnormalities were not being looked for, the suggestion of their possibility here would be overlooked or the findings perhaps classified as normal deviations.

The medical history of the parents of babies R. B. and J. B. was essentially negative. Both were fully developed healthy young adults. Wassermann and

Kahn tests upon both were negative. These have been repeated three times at intervals, with the same result. A Mantoux test on Mrs. A. J. B. was negative. Tests have also been made for possible endocrine disorders, with negative results.

The fact that the mother had a previous pregnancy by a man other than the father of the last three children, without a normal child being delivered, seemed to place the responsibility in this case upon the female side.

There was no traceable history of cleft palate or other objective abnormalities in the families of either parent. Several children of immediate relatives are normal. Brothers and sisters of both parents are normal.

Fig. 1.

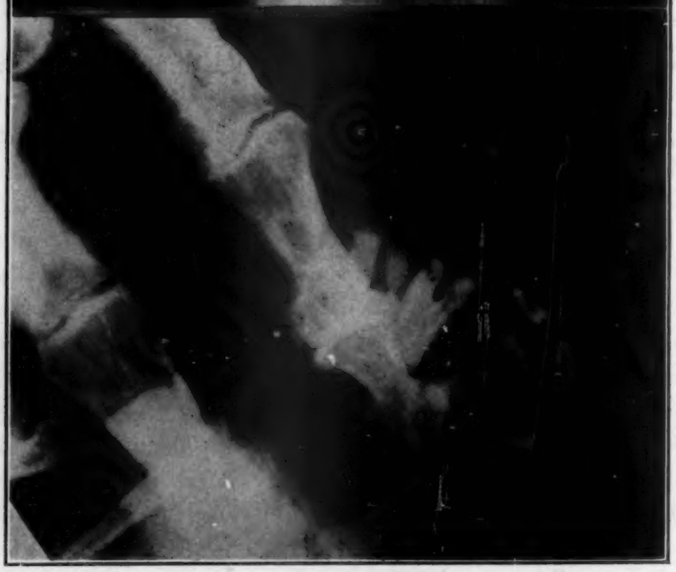

Fig. 2.

Baby R. B. was delivered at the termination of a full-term pregnancy without undue difficulty. Birth weight was $6\frac{1}{4}$ pounds. Abnormalities herein reported were noted in the face, feet, and hands. There was bilateral alveolar cleft of the palate extending backward through both the hard and the soft

palate and the uvula. There was an associated bilateral harelip with moderately protruding premaxillary process.

The hands and feet were of particular interest. The left hand, as shown in Fig. 1, was normal in all respects. The right hand, Fig. 2, had six fingers and, as shown by the x-ray, there were six sets of phalanges and five metacarpal bones. The middle metacarpus, partly obscured by the hand of the attendant, was bifid, acting as the metacarpal bones for the third and fourth fingers.

The right foot had seven toes with six phalanges, one phalanx serving for the double big toe which was fused to within a short distance of the tip. There were five metatarsi in this foot with a possible suggestion of a sixth, showing as a calcified area between the third and fourth. One large metatarsus served for both big toes.

Fig. 3.

In the left foot there were also seven toes with six phalanges as in the right, but there were six definite metatarsi, each big toe having its own.

Baby R. B. gained back its birth weight but did not gain any additional weight and died at the end of the seventeenth postnatal day of respiratory infection. This case is of especial interest because of the extremity abnormalities and the fact that a fourth pregnancy brought forth a child which may be normal. Sufficient time has not elapsed in the latter case to determine whether hidden anomalies exist or not in the latter case. It will be of interest to see if a subsequent female birth shows that abnormalities are confined to one sex, a possibility which must not be overlooked.

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A REVIEW OF SOME SURGICAL METHODS OF TREATING PYORRHEA

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TODAY, surgery, as one of the methods of treating pyorrhea, is fast becoming routine practice in the hands of a large majority of dentists. This method of treatment has been popularized in the last few years through clinics and writings by such men as Kirkland, Ward, Lundquist, Zemsky, and others.

For the treatment of pyorrhea by surgery there are several distinct methods of operating. Merritt[1] lists three types of surgical operations: (1) gum resection, sometimes referred to as gingivectomy, by which the gum forming the pocket is excised to or below the level of the involved alveolar process, and the root exposed; (2) a flap operation, consisting of two vertical and parallel incisions, usually limited to the buccolabial surfaces, the laying back of the gum flap, and the exposure of the field to be operated upon; (3) in those cases in which there is a group of several teeth to be operated upon, the septal gingivae between the individual teeth are incised to the floor of the pocket, the buccolingual gums are forced back in such a way as to gain direct access to the field of operation. Following the operation, the separated gums are brought into place and sutured between each tooth.

Miller[2] classifies the surgical method of operating as follows: (1) radical surgery, which includes all types of tissue removal, whether by cutting, electric knife, or coagulation; (2) conservative surgery, which includes exposing affected areas for access and returning tissue to place after operation.

Ward[3] enumerates three methods of surgical eradication: (1) gingivectomy, (2) flap operation; (3) obliteration method.

The historical development of surgery as a method of treating pyorrhea has its beginning with the Robicsek[4] operation performed in Vienna, in 1862. This operation was a typical gingivectomy. It consisted of treating cases of pyorrhea by an excision of the infected gum tissue followed by a scraping of the exposed bone.

Between 1862 and 1912, several articles appeared in the dental literature, under various titles, referring to surgery as a method of treating pyorrhea, but an examination of this literature reveals that it referred to surgery of the root surface or subgingival curettage. Some articles give Riggs credit for resorting to surgery at times, in his treating of periodontal lesions, but Merritt assured Berger[5] in a personal communication that Riggs did not practice surgery but expressed his opinion that it was a barbarous operation.

It was not until 1912 that a detailed description of a surgical technique appeared in print. This was presented by Pickerill[6] in his book, *Stomatology in General Practice,* in which he described an operation for pyorrhea and called it a gingivectomy. The operation consisted of the following: "The calculus is rapidly removed, laceration of the tissues does not matter in the least and the hemorrhage is controlled by an assistant. Then, by means of special curettes,

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curved scissors, etc., the whole of the infected tissue is removed, applications of tincture of iodine are made frequently, and massage is undertaken as soon afterward as possible. The patient is put upon a mixed diet of fibrous and acid carbohydrates, proteins, and extractives being reduced to a minimum."

In 1914 Cieszynski[7] a Polish physician specializing in stomatology, outlined the following guiding principles for a flap operation before the Central Association of German Dentists: (1) the obtaining of a convenient surveyable entrance, whereby the roots may be thoroughly cleansed of calculus; (2) the radical removal of the granulation and the epithelial ropes from the tooth pockets; (3) removal of the protruding bone edges of the alveolar and filing of the same; (4) disinfection of the diseased focus; (5) the radical removal of the tooth pockets which form the source of the suppuration; (6) removal of the gingival papillae by means of a crater-formed incision, that is, obliquely to the axis of the tooth, so as to get rid of the epithelial covering on the pockets, and also to avoid leaving any broad space uncovered by the mucose tunicle which might lead to the formation of caro luxurians. In this way a new ligamentum circulare is formed, after suture; (7) the operation is to be executed by the lancet and sharp spoon, not by galvanacantery, as this instrument is likely to disturb the periosteum, thereby creating less favorable conditions for the treatment of the disease; (8) after the cure has been completed a maxillary bone already lost through regressive process is never restored, though the teeth become more firmly fixed in consequence of the cicatrization of the mucose tunicle.

Due to the World War, however, Cieszynski's works did not reach the dental profession in general, until several years after publication.

Black[8] in 1915 published a book entitled *Special Dental Pathology*, in which he describes a method of eradicating the pocket. He describes his method in the following manner: "In many cases, the best method is to partially or entirely eradicate the pocket by cutting away the gum tissue that is undermined by the disease of the periodontal membrane. This should be cut away as far as the greatest depth of the margin of the alveolar process as well as the soft tissue, since the detachment of the periodontal membrane from the cementum is usually in advance of the destruction of the bone." Black's technique can be classified as a gingivectomy or a modification of the Pickerill operation.

In 1917 there appeared a publication by Widman[9] written in Swedish, which was later published in English, outlining a detailed description of the flap operation. Widman's rules embraced the following principles: (1) complete exposure of the granulation tissue; (2) total extirpation of the granulation tissue which causes decay of the bones; (3) the absolute removal of the concretions at the roots.

At the sixty-ninth annual session of the American Medical Association held in Chicago, June, 1918, Zentler[4] presented his flap technique before the section of stomatology. His technique consisted of the following: (1) making two parallel incisions, starting at the cervical free border of the gingival and carrying them apically to the apical region, each side of the area over the teeth being involved; (2) raising the flap from the gingival margin apically; (3) inflammatory and granulomatous tissue curetted; (4) the diseased alveolar bone chiseled away, and its rough edge smoothed so as to form an even surface for the roots.

Neumann[10] in 1920, made the following rules for a flap operation, which he cites in 1921. His rules are: (1) distinct survey of the entire field of operation; (2) complete removal of any remaining concretions on the roots; (3) complete removal of all granulation tissue interwoven by epithelial ropes in the niches and inlets of the teeth; (4) complete removal of all pathologic bone structure incapable of regeneration; (5) removal of the gingival pockets by excision of the diseased pituitous tunicle over the diseased bone; (6) destruction of the bacterial focus in the pockets.

November 12, 1920, Nodine[11] lectured before the American Dental Society of London on, "Surgical Treatment of Pyorrhea." The paper was later published in an American dental journal. Nodine's technique with the exception of slight variations is similar to the technique which Black outlined in 1915.

December 20, 1920, Ziesel[12] read a paper before the Eastern Dental Society of Philadelphia, in which he presented an outline for a simple and direct surgical operation for pyorrhea. This operation, he termed gingivo-ectomy.

Shearer[13] in his paper, "So-called Surgical Treatment of Pyorrhea" published in 1924, advocated the flap operation rather similar to Zentler's but according to the author, offered the following advantages: "Much larger areas can be operated upon, which may include all maxillary or all mandibular teeth. The entire mouth may be thus operated upon in two sittings, one week apart, which makes it possible to complete all the work in a very short time. Besides, it is unnecessary to contend with 'sore mouth.' "

Zemsky's[14] technique, which he called the "Open View Operation" was published in 1926. Eleven years later he again published his technique calling it, "The Open View Plastic Operation."[15] A comparison of Zemsky's operation with Zentler's reveals very little difference in the first stages of the operation, but some variations appeared in the later stages.

Zentler curettes the inflammatory tissues and smooths the edges of the bone, the flaps are coaptated and sutured, while Zemsky curettes the inflammatory tissue and cuts the alveolar border away, then the gingival margin with all the underlying diseased structure is eradicated. The flaps are replaced so as to leave a space between the outer and inner flaps and around the roots, then sutured, which leaves an exposed alveolar ridge to be covered with granulations.

Zemsky claims the following advantages for his operation: (1) complete eradication of the pockets; (2) prevent recurrence through reinfection due to lack of attachments; (3) prevent nonunion of the lingual and palatal flaps with their corresponding buccal and labial flaps; (4) thoroughly remove all the infected and disintegrated structures, thus eradicating the oral foci of infection in advanced cases of pyorrhea; (5) obtain the desired results quickly and easily.

In 1928 Ward[3] published his technique which he classified as an obliteration method of pocket eradication. This technique included the application of a surgical cement to be applied over all operated areas. The introduction of this cement marked an advance in the surgical operation and was readily adopted by dentists who resorted to surgery as a method of treating pyorrhea.

The following year Kaiser[16] published a technique very similar in character to Ward's.

There is no doubt that Kirkland's[17] modified flap operation, which he presented to the dental profession in 1931, is the most conservative of the surgical methods advocated by the various authors. His method consisted of separating the interdental gingival papillae by making a horizontal incision through the center. With periosteotome, one flap is retracted labially or bucally, according to location, and the other lingually. Both are retracted to a point slightly beyond the depth of the lesion. With the fork, the flaps may be opened wide enough to insure free movement of the instrument and to provide an unobstructed view in the field of operation. Four years later he published his semiflap technique[18] which consisted of the modified flap, labially or bucally, and a gingivectomy in the lingual area.

In 1932, Crane and Kaplan[19] published a technique of pocket eradication which is a modification of the Ward method. In their method of operation, only the actual pockets are removed, leaving an irregular gingival marginal crest.

A critical analysis of the various methods of surgical interference in the treatment of pyorrhea, reveals that they are all modifications of two methods as classified by Miller: (1) removal of affected tissue (gingivectomy); (2) exposing the affected area for access and returning the overlying tissue to place, after the operation (flap operation).

A chronological summary of the various methods, originators, and dates according to the above classification is: (1) gingivectomy; 1912 Pickerill, 1915 Black, 1920 Nodine, 1920 Ziesel, 1928 Ward, 1929 Kaiser, 1932 Crane and Kaplan; (2) flap operation; 1914 Cieszynski, 1917 Widman, 1918 Zentler, 1920 Neumann, 1924 Shearer, 1926 Zemsky, 1931 Kirkland.

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THE ADMINISTRATION OF NITROUS OXIDE AND OXYGEN

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THE administration of nitrous oxide and oxygen involves many subsidiary, auxiliary, and collateral considerations, but in this discussion we will confine ourselves to the modus operandi of actual administration, under ideal conditions. Variations from normal will be touched upon superficially but in sufficient detail to acquaint the reader with the fact that each individual presents some variation from the ideal, however slight it may be in a given case.

The patient should have no food for three hours before general anesthesia; administer some synergist such as morphine, atropine, etc., about an hour before the operation; the bladder should be emptied just prior to being seated in the operating chair and all tight clothing loosened. It is, of course, desirable to perform a blood test, urine test, and make a thorough physical examination (and this is routine in hospitalized cases), but it is impractical for the dentist in his office to do all these things preparatory to an extraction which may take but a minute or two. The practical course is to observe the patient generally. Stocky patients with short necks are frequently difficult to manage; vigorous, overstimulated patients do not respond to anesthesia as easily as septic individuals or those who have become fatigued through pain and lack of sleep.

A test which can and should be made in each case is the breath-holding test. If the patient passes this test, he is usually a safe subject.[1]

If the patient has a moustache, or is unshaven or bearded, use a small, damp towel, drape over face so as to expose nose and mouth, first placing a piece of damp cotton over moustache, to prevent leakage of gases. Most of the air will be thus excluded by pressing the margins of inhaler against the towel and cotton.

Determine from your observation whether the patient is a good, fair, or poor risk,[2] and in the latter case be alert for changes from normal reaction, taking immediate steps to induce a return to normal.

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[1]Breath-holding test. Seat patient comfortably in chair and request him to breathe through the nose for several seconds; warn him that a test is about to be performed. At the end of an EXPIRATION, pinch the subject's nostrils together with the thumb and forefinger of left hand while the right palm covers the closed mouth. When this has been accomplished, inform him that you are attempting to time the interval during which he can resist breathing. A perfectly normal individual is capable of maintaining an apne'c pause ranging from 30 to 45 seconds. Any person who is unable to hold the breath for at least 20 seconds may be considered to be a poor risk, since he is probably suffering from cardiac, respiratory, acid, or blood disturbance. This test is reliable.

Vital capacity test. The vital capacity test is a means of determining impairment of respiration. Fill the lungs with air as completely as possible. Blow this air into a spirometer (Bellows type spirometer or McKesson-Scott vital capacity apparatus) until the lungs are as completely exhausted as possible. The normal vital capacities (A. Myers, Vital Capacity of the Lungs) according to height and sex, are arranged in a table so that the percentage above or below normal may be obtained without computation. Vital capacities above normal have no bearing; but vital capacities of less than 50 per cent normal should be investigated to determine the nature of the lesion before operating. The vital capacity test does not determine the cause or nature of the disease, but is a reliable method of measuring degree of respiratory limitation (Seldin).

[2]Good patients may go in and out of cyanosis without any ill effects other than nausea or vomiting. Fair risks do better in the hands of an experienced anesthetist. Bad risk patients are the problem. Here the dentist is at a marked disadvantage compared to the physician. The physician has his patient in the hospital a day or two before operation; a complete history has been taken; blood studies have been made; the physical examination has disclosed conditions which determine the choice of an anesthetic; the patient is a known factor. The dental anesthetist administers nitrous oxide to any patient who desires it at any time without any definite knowledge of his physical condition. It is fortunate that most anesthesias performed by general dental practitioners are of such short duration that actual surgical anesthesia is rarely reached. If it were not for the shortness and lightness of these anesthesias mortality statistics would show a marked increase. It is difficult to conceive a general surgeon administering his own general anesthetic and operating at the same time. Nevertheless this seems to be expected of the dentist (Jacobs).

The apparatus is tested and adjusted to the probable requirements of the patient at hand, who, we will assume, is a normal patient, an ideal case from all appearances. If the operation is to be a long one, the mouth hook (for administration while the operation is in progress) should be placed within easy access.

The patient's head, neck and body are placed in a straight line, tilted back at an angle of approximately 75 degrees, chin up, hands clasped in the lap. The mouth prop (used in pairs with string attached)[3] is applied; the mouth pack[4] (also with string attached) placed where it can easily be reached, and a hypodermic of novocain ready for use in case it is later desired to finish the operation under local anesthesia. All other necessary and emergency instruments are close at hand, but covered so the patient will not be alarmed.

Before opening the valves on the apparatus, let us review the three stages of anesthesia:

First stage: This is characterized by a peculiar tingling or benumbing sensation in the periphery and acuteness of the senses, particularly the sense of hearing.

Second stage: Partial loss of sensation, pallor of the face, muscular relaxation, perhaps snoring.

Third stage: The respirations are slow and deep and at times stertorous; loss of sensibility both to pain and external impressions; loss of eyelid and eye reflexes; fixation of eyeball. The temperature increases slightly during the process of anesthesia. This stage is divided into three planes: light, surgical, and profound.

The gases are started flowing in the nasal inhaler at the previously determined rate and mixture (in this case at the rate of three and one-half gallons per minute, oxygen at 3½ per cent, nitrous oxide at 96½ per cent) and the inhaler applied to the patient's nose, wide end at the nostrils. This is now tightened at the back of the head with the rubber hose running below the ears. If it is fastened above the ears it will tend to slip off the head. The gases to the mouth cover are now turned on and the mouth cover applied tightly so there is no escape of the gases. If it cannot be made airtight, a damp towel is applied about the mouth, and the mouth cover is placed over it. When the nasal inhaler is first applied, the air valve is wide open. When reflexes disappear, screw down this valve until there is barely an escape. This gives about 80 per cent of rebreathing. By screwing this valve all the way down rebreathing is complete. This is done just before beginning to operate.[5] The safety valve on the gas apparatus (for controlling pressure of the gases on the lung tissue) should be adjusted at 20 to 40 for adults, less for children.

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[3]This is done to facilitate changing when both sides of the jaw are to be operated upon at one sitting. When the operator is finished with one side of the jaw, the hanging mouth prop is placed in position on that side, and the other one removed from the mouth, to remain in the hanging position.

[4]Mouth pack is preferable to the term "throat pack" since it is intended to keep the throat open or curtained off from the mouth, so that the gas will not be deflected into the mouth in its passage from the nose to the throat; and to prevent the contents of the mouth reaching the throat. A happier phrase has been used in the term "mouth curtain."

[5]I have discussed the subject of rebreathing in a separate paper, which includes the interesting topic of carbon dioxide balance in the organism, Dental Items of Interest, February, 1939.

Administration is continued until the patient's eyeball commences to oscillate (15 or 20 breaths). Lightly touch the eyelash, and if there is no reflex, pick up the eyelid. Now look at the eyeball for reflex. If the eyeball is in central position and fixed, with no dilatation of the pupil, and respiration uniform with even rhythm and amplitude, the patient is in normal operative position.

The mouth cover is removed, gas turned off from the mouth cover and the rate of flow in the nasal inhaler increased to five and one-half gallons per minute, and the oxygen increased to 10 per cent. This percentage is adjusted to permit more or less oxygen to flow during the course of the operation, depending upon the reaction of the patient. Once the oxygen equilibrium of the patient is determined changes in percentage should be avoided. An ideal mixture for the normal case is 12 per cent oxygen and 88 per cent nitrous oxide. The mouth pack is placed not too far back on the tongue. This is done by rolling the gauze throatward close to the palate, over but not on the tongue. This avoids pushing the tongue back, which may cause respirational embarrassment. The surgeon may now proceed with the operation.

When the patient is properly anesthetized there should be an increased rate of respiration, relaxation of muscles of the eyelids, rose-colored earlobes and fingernails, insensitive conjunctiva, stationary or slowly rotating eyeballs, general muscular relaxation. If the eyeball is in the center but oscillates considerably from side to side, or if it is fixed upward or downward, it indicates oxygen want[5] and the oxygen is immediately increased 5 per cent to 10 per cent until the eyeball is back in the centric position, this being the surgical plane. When the eyeball is off centric, it is a sign of profound anesthesia and danger.[6] If there is muscular twitching,[7] retching,[8] vomiting, irregular respiration with prolonged exhalation, dilated pupils, these symptoms indicate oxygen want, and the percentage of oxygen is increased. Retching may also be caused when pure oxygen is being *forced*, in which case oxygen is reduced.

Cyanosis indicates a deficiency of oxygen. The oxygen is turned on pure (no nitrous oxide) for a few inhalations until the normal color returns.

The anesthesia is too light if the patient struggles,[9] if there are voluntary reflex movements, holding of the breath, mumbling, crying. If the patient is an alcoholic or is otherwise excessively stimulated (heavy-set, vigorous type), the oxygen is turned off completely and pure nitrous oxide is administered until smooth anesthesia is obtained. In *light anesthesia* the inhalations are prolonged and exhalations short, or the patient may hold the breath for a long time. In

[5]Anoxemia.

[6]Contraction and dilatation of pupil are valuable indications of depth of anesthesia. It is within the experience of every anesthetist to have commenced administration only to discover that pupillary reflex is not normal. Therefore include examination of pupil before administration of anesthesia. Test each pupil individually for light reflex with pocket flashlight; test for reaction to distance by asking patient to gaze off into space; when pupil is expanded, place finger three to four inches in front of eye; pupil will contract. There are four principal abnormalities of pupillary reflex (Cabot) which are of interest: 1. Argyll-Robertson pupil: distance reflex normal; response to light absent. Diagnostic of dementia paralytica and tabes dorsalis. 2. Dilated pupil: tubercular patients show transitory relaxation of one or both. 3. Contracted pupil: present in old age, photophobia, tabes dorsalis, paralysis. 4. Contraction with irregular outline and sluggish reactions, indicates iritis or syphilis (Seldin).

[7]Subsultus tendinum.

[8]Strong involuntary effort to vomit.

[9]Struggling is overcome by the use of straps or force.

profound anesthesia the inhalations are strong and exhalations prolonged. The breathing is rhythmic in the deep-seated stage. If the patient's breathing becomes labored, it indicates oxygen want. Give pure oxygen (no nitrous oxide) for several inhalations until breathing is normal. Normal breathing under nitrous oxide is determined with experience.

Do not allow the chin to sag; keep it up, as sagging interferes with the airway. "Keep your chin up" is an excellent maxim here as elsewhere. Watch the color of the blood at the ear, in the mouth, and at the finger tips. These points give the first indications of approaching cyanosis.

If there is respiratory embarrassment from the tongue, use a soft rubber airway, first removing the mouth pack.[10]

The pulse may be taken at the temporal, facial, or radial artery.

If there is swallowing of blood or an accumulation in the throat, this may be cleared with pure oxygen under pressure. This will blow the accumulations out of the mouth. Keep your face out of the way, as the blood is expelled quite forcibly.

Enlargement of the pupil is a danger sign and indicates oxygen want. Give pure oxygen (no nitrous oxide).

Swelling up of the entire body is a similar sign and treated similarly.

As already stated, there is muscular relaxation in the normal surgical plane. Stiffness of the musculature and flopping of the patient are signs of oxygen want. Increase the percentage of oxygen in the gas mixture.

When the operation is concluded, the mouth pack is removed, first giving the patient a few inhalations of pure oxygen. The nasal inhaler and mouth pack are removed as the patient shows signs of returning consciousness. The administration of a few breaths of pure oxygen at the conclusion of the operation will many times prevent struggling, if there is such a tendency, by bringing the patient out of the anesthesia quickly, so that when he passes through the excitement stage it is almost imperceptible. The patient's head should be held in the crook of the arm to prevent movement.

Difficulties may be avoided and controlled by a thorough understanding of each patient's psychologic makeup and reaction to the gases at the instant of the reaction, and by attention to detail. Among these details may be mentioned:

1. An empty stomach.
2. The proper use of premedicating agents. Premedication with morphine or atropine is indicated with alcoholics, plethorics, athletes, nervous patients, and those suffering from tuberculosis, high blood pressure, and hyperthyroidism.
3. Emptying of the bladder.
4. Keeping instruments concealed.
5. Proper position of head, neck, and trunk.

[10]In case of obstruction by the tongue, the tongue may be more easily, quickly, and safely brought forward by passing the index fineger of one hand backward alongside the tongue at a point just above the epiglottis, the cartilage of which can easily be felt, and thus carry the whole tongue forward. It is very important that the finger should reach back to the point indicated because the widest diameter of the tongue is near its middle and if it is grasped as its largest diameter or just anterior to it, the finger will slip off without bringing the tongue forward. When the finger is used in this way, it not only brings the tongue forward but opens the air passages because it stretches the glottis and opens the epiglottis, and the tissues of the throat cannot close so tightly about the finger but that air can enter (Heidbrink).

6. Rapid induction of anesthesia in overstimulated types, to carry the patient quickly past the stage of excitement. Saturation of the overstimulated type of patient who resists the nitrous oxide, by using the nitrous oxide pure (without oxygen) until the patient shows evidence of deep narcosis, then guiding the subject into the light plane by the addition of oxygen, and finally into the surgical plane of the third stage. This is referred to as the quick induction method. The same object may be accomplished slowly by administration to the patient of a minimum percentage of oxygen for about five minutes or until he is well saturated. Anemics, on the other hand, require slow induction of the anesthesia with a large percentage of oxygen in the gas mixture.

7. During the progress of the operation the gases must be delivered evenly and with sufficient pressure to prevent dilution by air inspired through the mouth. In a long operation the oxygen percentage is slightly increased from time to time as the operation proceeds.

8. Employment of restraining straps whenever the operator anticipates they will be required, the adjustment to be made after anesthesia is induced. A knowledge of effective holds in such an emergency is tremendously helpful. If the patient is a child, a roller towel is placed over his head and rested on his arms. The operator places his foot through the other end of the towel. A backward jerk of the leg will hold the arms and body tightly against the back of the chair and prevent the child's body from sliding down.

9. Never undertake nitrous oxide and oxygen anesthesia without adequate assistance, and positively never alone.

10. In the case of bearded or unshaven men, an anesthetist may carefully regulate the percentage of nitrous oxide and oxygen on the dials of the apparatus while air seeps in between the patient's beard and moustache and inhalers to nullify all his care. As already stated (and here repeated for emphasis), this will be avoided by applying a small, damp towel over the face, allowing only the mouth and nose to remain exposed; and a piece of wet cotton over the moustache. By placing the margins of the nasal inhaler and mouth cover against the margins of the cloth and cotton, the air will be satisfactorily excluded.

Let us now discuss the third stage of nitrous oxide and oxygen anesthesia. The third stage of anesthesia is divided into three planes: Light, normal (surgical or operative), and profound. The profound plane may not be maintained except momentarily in securing complete, or what may be termed secondary, saturation with nitrous oxide. For major dental surgery normal anesthesia is required, but it is often necessary to invade the profound plane momentarily in order to maintain the normal anesthesia. In light anesthesia the respirations are quiet, normal, and subject to reflexes due to trauma. In this stage breathing may be slow, regular, and superficial, with inspiration longer in duration than exhalation. The breath may be held, with grunting or phonation due to pain stimulation. These signs must be differentiated from similar signs when the patient reaches profound narcosis. As light anesthesia is deepened to normal anesthesia the respiration changes to a machinelike rhythm in which the inhalations and exhalations are practically equal in duration. The rate is usually increased, with no phonation or grunting response to ordinary trauma. A further deepening of

anesthesia to a profound or dangerous degree is indicated by the respiration becoming regular, slower than normal, and showing variable degrees of prolonged exhalation. This later sign differentiates this stage from light anesthesia. Phonation may occur in either inhalation or exhalation, but is of an unusual character. The spasticity[11] of muscles during exhalation, due to a deficiency of oxygen, finally arrests breathing. This may be re-established by supplying the patient with pure oxygen (no nitrous oxide). Because of the contracted muscles, the oxygen should be forced for two or three inhalations, after which breathing will re-establish itself, provided, of course, that the respirations have not been arrested for too long a period of time. The anesthetist must be alert to discover these symptoms and must instantaneously correct them.*

The two reactions of muscle, flaccidity[12] and spasticity, are fundamental. The first is indicative of normal anesthesia and the second of anoxemia.[13]

General Muscular Phenomena.—In addition to what has already been said on the reaction of the musculature in nitrous oxide and oxygen administration, muscular response is of importance in determining the plane of anesthesia. The facial expression, movements of the extremities, swallowing, retching, and vomiting are among the most common symptoms to be observed by the anesthetist. In *light anesthesia* the facial expression may be indicative of pain though unconscious of trauma, and the extremities move with more or less direction. In *normal anesthesia* (operative plane) the general musculature is quiet and relaxed. In *profound anesthesia* bordering on the dangerous, the muscles are spastic or rigid, so that the patient may straighten out the legs and force himself over the head rest.[14] Such phenomena are observed after the patient has been anesthetized for some time. In the beginning of narcosis, profound anesthesia is more often indicated by clonic[15] movement or jactitation.[16] In this stage the vomiting reflex is often excited. Swallowing, retching, and vomiting are the sequences of this reflex so that when any one of these symptoms appears it will be aborted by increasing the percentage of oxygen in the gas mixture. There are, of course, other causes of vomiting which do not depend upon the anesthetic and would, therefore, be uninfluenced by the change in the mixture.†

Eye Signs.—In *light anesthesia,* stroking the eyelashes elicits reflex winking, as does also opening the lids, or touching the conjunctiva. The pupils are smaller and contract very slowly to light, or not at all, while the eyeballs are fixed or roll slowly. In *profound anesthesia,* the eyelids are flaccid and do not resist when pulled open, winking cannot be elicited, although in some cases the eyes stand staringly open from spasm of the muscles; and when there is muscular twitching, incomplete winking movements may be noticed. The pupils do not react to light but enlarge progressively until only a narrow margin of iris may be seen. The

[11] Involuntary contraction; spasm.
*Resuscitory methods may be found in any good book on first aid.
[12] Relaxed.
[13] Deficiency of oxygen in the blood.
[14] By removing the upright at the end of the footrest of the chair this may be avoided.
[15] Spasm in which rigidity and relaxation alternate.
[16] Tossing of the body to and fro.
†McKesson.

appearance of the eye is a trustworthy sign and no time should be lost in increasing the percentage of oxygen when this enlargement of the pupil appears. The eyeballs are usually fixed but may jerk from convulsive contractions of the external eye muscles. These eye signs may be observed whether morphine has been administered or not and are so important that no patient should be anesthetized without their guidance (McKesson).

ABNORMALITIES AND DISEASES

Any or all of four great systems are involved in the administration of nitrous oxide and oxygen: respiratory, circulatory (including cardiovascular apparatus), renal, and endocrine.

Respiratory System.—The *nasal passages* may be obstructed by growths or abnormalities. This occurs principally in children and adolescents but may appear also in adults. The patient with enlarged adenoids presents a short, functionless upper lip, slightly parted lips, narrow nostrils, stupid facial expression. In adults, deviated septa, hypertrophic neoplasms, or septal spurs may be present. Test the ability of the patient to breathe through the nose by covering the mouth with the palm of the hand. If there is sucking in of the nostrils, nasal obstruction is present. This condition may be overcome by increasing the pressure of the gases or by use of the nasopharyngeal tube.*

Infections and tumors of the neck and air passages, such as retropharyngeal abscesses, cellulitis, and edema of the floor of the mouth, tumors of the neck exerting lateral pressure against the lower pharynx and trachea, tend to restrain the free passage of the gases. Increase the gas pressure or use nasopharyngeal tube.

Asthma is recognized by reversal of the respiratory rhythm. Inspiration is hardly more than a gasp, expiration is prolonged with a lasting wheeze. The entire respiratory cycle is dyspneic or difficult. This is no obstacle to the use of gas, but the pressure should be increased. The onset of the anesthetic may be slower due to poor ventilation of the lungs or retarded absorption of the gases.

Dyspnea or Cheyne-Stokes Breathing.—Accelerated breathing should not be confused with difficult breathing of dyspnea, the latter caused by disease. The symptoms of a patient suffering from labored breathing resemble those of a long distance runner at the point of exhaustion; the lips and face are dusky, patient is yellow, the chest heaves. Ordinary dyspnea does not preclude the use of gas if sufficient oxygen is supplied to avoid deepening the anesthesia to the point of crowing and long jerky expirations. Should there be apneic intervals between short dyspneic spasms, it indicates partial paralysis of the respiratory center. This is Cheyne-Stokes breathing and is no contraindication to the use of gas but requires the presence of a physician, since a dentist is not legally permitted to sign a death certificate. Cheyne-Stokes breathing disappears during anesthesia and reappears when the anesthetic is removed.

Diseases of the Lungs.—General cachexia or weakness, emaciation, midafternoon fever, circumscribed flushing of the cheeks and hacking cough are some of the symptoms of chronic pulmonary tuberculosis. Inject 1/6 gr. morphine to reduce oxygen requirements 1/2 hour before anesthesia. Keep head on line

*To be substituted for the nasal inhaler after anesthesia has been induced.

with the body and pharynx well open to prevent obstruction of the air passages. Other lung diseases, such as emphysema and pneumonia, are suspected by marked cyanotic or bluish coloration of the lips. Handle patient the same as for tuberculosis. After the operation hospitalize the patient.

Bronchitis, accompanied by hard coughing, asthma, and emphysema, increases the blood pressure by venous congestion and eventually weakens the heart. Nitrous oxide with care is not contraindicated, but the anesthetist should be selective as to age, length of illness, and general condition. Hospitalization is recommended.

Carcinoma of the Lungs.—Patient should not be given inhalation anesthesia because of possible dissemination of the process.

Vincent's Infection.—Cutler has shown that an extremely large number of lung abscesses are positive to Vincent's organism. The fact that these abscesses clear up rapidly under intravenous arsenicals is convincing proof that these organisms are a factor in the production of these abscesses. Even though the throat may be securely curtained off, some inspiration may take place. Inhalation anesthesia is, therefore, undesirable until the organism has disappeared.

Tumors.—The presence of a tumor within or outside the respiratory tract from the larynx down requires expert skill in the administration of nitrous oxide and oxygen. The position of the head and neck may have to be placed unorthodoxly to secure unembarrassed respiration.

In connection with respiratory diseases, the student should familiarize himself with the minute anatomic arrangement of the lung tissues, as such an understanding will be of invaluable assistance.[17]

Circulatory System.—Every dentist should have blood pressure apparatus and stethoscope to determine, in case of doubt, which cases may be given a general anesthetic in the office and which should be hospitalized. Abnormally high blood pressure with degenerative disease is a contraindication to the administration of gas in the office. If the case is hospitalized, it requires extreme watchfulness and the presence of a physician.

Cerebral arteriosclerosis may induce cerebral hemorrhage during any excitement, mental, emotional, or physical. The diastolic pressure represents the pressure which the left ventricle must overcome before the blood will begin to circulate. The presence of a diastolic pressure of 100 is significant of serious trouble; 110 is a menace; over 120 is extremely dangerous (Osborne). The anesthetist should be guided by the pulse pressure (difference between systolic and diastolic). As long as good pulse pressure is sustained the heart may withstand the shock and excitement of nitrous oxide.

Anemia calls for skill in administration of gas, especially if the hemoglobin is 50 per cent or lower. Color, in this condition, is no index of the depth of anesthesia; the anesthetic range is difficult to determine, and the patient may remain listless for a long period. Pulse should be observed in radial artery in the wrist by feeling with index, middle, and ring fingers. The thumb should never be employed for this purpose. Anemia is diagnosed by pallor of mucous membrane

[17]A description of these structures, together with a short discussion of the physiology of respiration, will be found at the end of this article.

of lips, conjunctiva, tissues beneath fingernails, edema of eyelids. Give morphine $\frac{1}{6}$ gr. hypodermically. Use high level of oxygen at induction and gradually reduce.

Hemorrhagic Diseases.—Purpura, hemophilia, acute leucemia, manifested by persistent nosebleeding are among these. Presence of encrusted, coagulated blood in nostrils will indicate recent nosebleed. These do not affect anesthetic technique but do suggest taking proper measures for control of postoperative hemorrhage. Registration of blood pressure has inestimable diagnostic value. Systolic pressure represents pressure of blood in brachial artery at height of contraction. Diastolic is the pressure at resting stage. Pulse pressure is the working range pressure of the heart. Pulse pressure is computed by subtracting the diastolic from the systolic reading.

During induction with nitrous oxide there is a slight rise in systolic and diastolic registrations due to increased pulse rate. As the patient approaches the third stage the pressure becomes normal. In the deep stage of narcosis there is a slight rise followed by a marked fall. A progressive drop indicates surgical shock.[18] High systolic suggests functional disturbance in circulation; high diastolic indicates pathologic changes. Accordingly, diastolic in excess of 100 signifies pathologic condition somewhere in the arterial system and points to cardiorenal disease. Systolic varies greatly with emotional state, exertion, etc., but diastolic is unaffected by external conditions and is a reliable guide. Therefore, serious hypertension may be suspected when diastolic pressure persists at 120; sustained diastolic of 130 or more presages fatal determination within two or three years and consequently poor anesthetic risk. The greater the difference between systolic and diastolic, the greater the heart load and danger of heart failure.[19]

Diabetes is indicated by an odor of acetone, new mown hay or rotting apples, catarrhal stomatitis. The danger with the diabetic patient is not the anesthesia but the surgical procedure. Repair may be retarded and infection and necrosis follow. No surgery should be instituted until the sugar content is restored to normal. When surgery is permissible, give a hypodermic of morphine $\frac{1}{6}$ gr.

Cardiovascular System.—This is composed of the heart, blood vessels, and blood. Heart disease may be of the valves, muscles, and coronary vessels. *Valvular* diseases are associated with compensation or decompensation. Properly administered and psychic shock controlled, nitrous oxide is the safest anesthetic for mouth surgery of short duration on patients with compensated valvular heart lesions.[20] The signs and symptoms of a decompensated patient are blue lips, short

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[18] Evans, Adams, Barach place normal systolic pressure between 110 and 140 regardless of age or sex; normal diastolic between 74 and 94; normal pulse pressure between 39 and 50.

[19] Dr. Charles W. Moots, of Toledo, O., has worked out a valuable means of determining anesthetic risk. He computes index of operability in the form of a proportion between pulse pressure and diastolic pressure—the normal operative ratio—calculated by dividing the pulse pressure by the diastolic pressure, being between 25 per cent and 75 per cent. If it is less than 25 or greater than 75, the case is considered inoperable for *major* oral surgery. The *energy index,* as computed by Dr. Barach, gives valuable information for determining risks (such as possibility of apoplexy or hemorrhage). From the pulse rate is determined the number of systoles and diastoles per minute. The energy index is obtained by multiplying the sum of systoles and diastoles per minute by the pulse rate. For instance, if the following data are secured: Systole 120, diastole 70, pulse rate 72 per minute, then

$$S \text{ plus } D \times P \text{ equals } 190 \times 72 = 13{,}680$$

The normal index is from 13,000 to 20,000. When it is less than 13,000 general cardiovascular inefficiency is suspected; when above 20,000 excessive circulatory load.

[20] Local anesthetics containing even small amounts of suprarenin act adversely on such patients. Even without suprarenin, the sight of the syringe and needle and the manipulation of instruments in the mouth have a tendency to produce syncope.

breath, swollen ankles; patient may not be cyanotic. When such a condition is suspected, the breath-holding test is a valuable indicator as to the strength of the heart. One who cannot do this for at least 20 seconds should be suspected of having some cardiac involvement if the red cell count is normal. Inexpert administration of nitrous oxide may result in complete decompensation almost immediately and a long period of invalidism. It is known that endocarditis may be caused by microorganisms, generally streptococci, staphylococci, or pneumococci. The most frequent causes of endocarditis, however, are rheumatic fever, recurrent tonsillitis, and chronic sepsis. Since streptococcic endocarditis is associated with vegetative growths of bacteria on the heart valves, excitement under any anesthetic may result in a shower of emboli into the blood stream. As long as compensation is complete, slow induction of nitrous oxide with smooth maintenance for a short period is not contraindicated.

In the overstimulated or hyposusceptible type with chronic disease of the valves, with good compensation, a state of muscular excitement may put a sudden strain on the heart, breaking the compensation. Such a patient should be hospitalized before and after anesthesia.

Patients with myocardial degeneration following some previous infectious disease should be given nitrous oxide with caution. Acute myocarditis may develop fatty degeneration, weakening the heart muscle, and acute dilatation may occur and cause death or prolonged disability. A patient with myocardial degeneration, who is not of the overstimulated type, may be given nitrous oxide; in the overstimulated type it may lead to untoward results.

Patients with rolls of abdominal fat probably have fat on the pericardium and on the chamber walls of the heart. This type of heart is usually enlarged and respiration embarrassed. Under nitrous oxide the respiration is not regular, and smooth maintenance is difficult.

Diseases of the coronary vessels of the heart present no problem in nitrous oxide administration. If the patient has had an attack of coronary occlusion he will invariably say so, in which case nitrous oxide should not be given. Such a patient is in danger at all times, and any undue excitement may precipitate death. These patients do far better under local anesthesia containing no vasoconstrictor, providing a successful attempt is made to control emotional excitement psychologically. An attack of angina pectoris may be precipitated by any physical effort or emotional excitement. One patient may have numerous attacks and survive while others may die during the first attack. An antispasmodic is indicated. Nitroglycerin tablet $\frac{1}{100}$ gr. under the tongue before adjusting the inhaler, or amyl nitrite, a few whiffs with the first few breaths of nitrous oxide, will prevent spasm which may occur during the induction. Hospitalize the patient.

Cardiac efficiency is suggested by absence of edema and swelling of legs and ankles; no pitting on pressure, normal respiration (18 per minute), normal pulse rate (72 per minute in male, 80 in female; above 100 per minute before age 3). A range of from 60 to 90 per minute is within normal if other symptoms are negative.

Cardiac disease is evidenced by swelling of legs and ankles, pitting on pressure, dyspnea on slight exertion, pulse slow, rapid or irregular. Where the

anesthetist is not equipped to take blood pressure, a serious anesthetic risk can be anticipated by determining if the heart is unequal to ordinary tasks in the course of everyday activities.

Congestive Heart Failure.—The patient manifests symptoms of dyspnea on slight exertion; breathlessness on slight activity; blueness of lips and finger tips; deposition of fluid under skin of ankles. Nitrous oxide may be given in an emergency, preceded and followed by hospitalization.

Anginal Heart Failure.—Angina pectoris is characterized by pain in region of sternum under stress or effort. Hospitalize before and after anesthesia.

In general, if patient is able to walk up a flight of stairs without dyspnea or cardiac pain, he is a safe risk.

Alterations of the heart, such as fatty and fibroid degeneration of heart muscle, valvular derangement, myocarditis, may be handled by a hypodermic of morphine gr. $\frac{1}{4}$ with atropin gr. $\frac{1}{150}$, and by the avoidance of increased blood pressure by averting cyanosis and respiratory spasm. Hospitalize the patient.

Gastrointestinal Tract.—Jaundice or icterus, yellowish discolorations of skin and of sclera of eye. Bile in urine renders diagnosis complete; mental depression, itching, retarded pulse rate. Preliminary medication hypodermic of morphine $\frac{1}{4}$ gr.

Renal System.—Chronic nephritis and renal insufficiency bring on a generalized edema, edema of legs, feet, back, eyelids, and a pale, pasty appearance. Uremia is indicated by urinous or ammoniacal odor. If patient is not under treatment, apoplexy or uremia may be precipitated by injudicious use of nitrous oxide. Hospitalize patient and have physician present.

Endocrine System.—Advanced hyperthyroidism is associated with cardiac disease and with emotional disturbances. M. F. Lesses strongly emphasizes hospitalization where there is thyrotoxicosis.

Menstruation in some women is associated with enlarged thyroid gland. Experience would seem to indicate that there is no more hemorrhage in women during menstruation than otherwise. The position of the head and neck in these cases is an important factor in producing smooth anesthesia. The same is true with the enlarged thymus.

Hyperthyroidism is suggested by a strange, startled, frightened look, bulging eyes, quick birdlike motions, moist palms, swelling of neck, sleeplessness. (Grave's disease, thyrotoxicosis, should be suspected.) The chief difficulty with this type is the small margin of safety. Such patients are controllable after a hypodermic of morphine $\frac{1}{4}$ gr. with light anesthesia of short duration. If, in addition to the above symptoms of toxic goiter, there is arrhythmical tachycardia (fast, irregular rate), the patient is critically ill; death may occur suddenly. Do not anesthetize the patient without the consent and presence of a physician, nor continue longer than fifteen minutes, and hospitalize. Should the goiter be of such dimensions as to compress trachea, increase the pressure of the gas.

Status lymphaticus is a hyperplastic condition of the thymus, spleen, bone marrow, and the lymphatic system, occurring most frequently in children, and is characterized by waxy skin, inability to breathe upon excitement; the patient may expire upon least provocation. Hospitalize and have a physician present and have the anesthesia short. Prevent excessive backward bending of the head

in view of the fact that this produces elevation of the enlarged thymus resulting in strangulation by compression of the trachea between the sternum and the gland.

The action of nitrous oxide on normal cells, with normal internal respiration and metabolism, is far different from the action of the gas on pathologic tissues (Jacobs), yet many dentists have unknowingly administered nitrous oxide to patients having some form of heart, lung, or kidney condition. It would seem, therefore, that there are practically no contraindications to its use where the patient is hospitalized. Patients presenting the conditions above described should be hospitalized so that exacerbation of pathologic conditions may be controlled. Such patients need rest and quiet in bed following any general anesthetic. The journey home from the office after the anesthetic is not conducive to prompt recovery and may aggravate the general condition. Inexperienced operators are safer with nitrous oxide than with any other general anesthetic, and if death occurs, it is either from psychic shock, improper administration, or its use on a patient unfit for general anesthesia.

Extremes of age offer no obstacles in the absence of lesions. Youth may cause a little trouble because of adenoids or other pharyngeal obstructions which impede the passage of gas into the trachea. Such cases are recognized by short upper lip, narrow nostrils, and high arched palate.

Anesthesia will not endanger the fetus up to the ninth month of pregnancy. The only extra precaution necessary is to pass excitement stage as rapidly as possible and avoid overdosage, since oxygen deprivation and consequent jactitation of danger stage may either asphyxiate the fetus or produce miscarriage.

With all the conditions above enumerated the patient may be given nitrous oxide, but the risk is increased as the condition progresses so as to reduce the vital capacity of the lungs, and precautionary measures must be taken as indicated.

In this paper I have attempted to coordinate my own experience with the experience of those mentioned in the references in the successful administration of nitrous oxide and oxygen to properly safeguard the interests, life, and health of the patient as well as the peace of mind of the anesthetist and the operator, and no originality is claimed for anything herein contained. The writer has for the most part compiled his notes from the literature on the subject, credit for which is contained in the references at the end of this paper.

It might be stated that it is the well-considered thought of the writer that the anesthetist should be a licensed practitioner who should devote every moment of his time to the anesthesia and be responsible for that alone, leaving the operator to give his whole attention to the operation itself. Only then will success in nitrous oxide and oxygen administration approach its maximum and accidents their minimum.

CONCLUSIONS

1. Nitrous oxide and oxygen is the safest general anesthesia under all conditions.
2. Doubtful cases which require general anesthesia should be hospitalized.
3. Precautionary measures should be used wherever indicated.

4. Technique should be modified according to conditions present.
5. The anesthetist should take no part in the operation.

ANATOMIC ARRANGEMENT OF THE LUNG TISSUES

The air passes by way of the trachea into the bronchi, thence through the interlobular bronchi into the lobar bronchi (one to each lobe of the lung). After coursing through several other subdivisional bronchi, the air reaches the terminal respiratory unit commencing with the bronchiole. The smallest bronchiole is divided up to form respiratory (terminal) bronchioles, which further branch into alveolar ducts. These vestibules, as the alveolar ducts are called, lead into atria which serve as the anterooms for the air sacs. In the walls of the air sacs are the final air cells or alveoli. The important point to remember is that, beginning with the alveolar duct or vestibule, the system is lined with alveoli or air cells. Thus the alveolar ducts (vestibules) and atria have the double function of acting as passageways for the air sacs and of performing the same work as the air sacs themselves. Careful examination indicates that the walls of the individual air sacs lie very close together but are effectively separated by a fine network of small capillaries uniting the pulmonary artery and vein. By this arrangement, the blood in these vessels has air on both sides of it, being separated from the air by two thin layers of tissue: the epithelial membrane of alveoli and the endothelium of the capillaries.

Passage of Oxygen Through the Alveolar Wall.—Although the blood occupies the alveoli for only one second (Greene), the air passes through the double membrane (epithelium and endothelium) into the circulating blood. Here the hemoglobin unites with the oxygen of the air producing oxyhemoglobin, the red principle of oxygenated or arterial blood.

Respiratory Center.—A small area definitely localized in the floor of the fourth ventricle in the medulla oblongata (by Legallois in 1812) has been proved to be the central powerhouse of respiration, whence issues a continual rhythmic discharge of impulses controlling inspiration and expiration. To demonstrate the automaticity of this center it can be shown that, severing the nervous centers above and below, it will not interfere with the regular promulgation of stimuli so long as sufficient arterial blood is supplied to it. *Changes* in the arterial blood going to the respiratory center regulate the nature of the impulses issuing therefrom, producing either an increased or decreased respiratory rate. *Increase in respiratory rate* is caused by anoxemia due to respiration of air containing insufficient oxygen; by the substitution of nitrous oxide for oxygen; severing of a large artery permitting accumulation of venous blood; rebreathing of ordinary air, reducing oxygen content; carbonemia (increased concentration of carbon dioxide) due to administration of pure carbon dioxide or air containing a large amount of carbon dioxide; exertion. Continued anoxemia produces depression of the respiratory center with exhaustion and respiratory failure. When nitrous oxide is pushed too far a similar anoxemic condition is produced. *Decrease in respiratory rate* is caused by overoxygenation or decarbonization (reduction of carbon dioxide) due to failure to institute rebreathing when carbon dioxide is low; also by the washing out of carbon dioxide by rapid breathing. A decrease in oxygen or increase in carbon dioxide causes the medullary power-

house to send neural impulses, increasing the rate and depth of breathing. A decrease in oxygen or increase in carbon dioxide results in the issuing of efferent messages, reducing the frequency of respiration. The respiratory center modifies the efferent impulses it issues to the respiratory apparatus depending upon the afferent stimuli it receives, maintaining the optimum level of breathing by controlling the gas pressure of the arterial blood. This refers to the gas in the circulating blood as a unit, so that each region is uniformly supplied. Each organ in any given region draws upon this supply in accordance with its local needs.

The vagus nerve (pneumogastric, tenth cranial) is the chief afferent nerve of respiration, maintaining breathing at a faster rate. Experiments on animals, in which one or both vagi have been severed, demonstrate that the respiratory movements become less frequent. The mechanical expansion and contraction of the air cells or alveoli in the lungs initiate the afferent impulses transmitted by the vagus. The vagus also inhibits inspiration and stimulates commencement of expiration, the complete operation being approximately as follows: at the end of an inspiration, the distention of the air cells stimulates the terminal filaments of the vagus, with the result that afferent inhibitory impulses travel up the vagus to the respiratory center in the medulla which, in turn, reinforces and relays them through the efferent nerves concerned in respiration (phrenics, intercostals, efferent fibers of vagi) to the respiratory muscles. At the same time that the inhibitory stimuli are initiated, expiratory impulses are also brought to the center through the vagus and transmitted to the respiratory mechanism. As a result, inspiration ceases and expiration begins. Correspondingly, deflation of the lungs, and consequently of the air cells, produces afferent stimuli acting so as to terminate expiration and initiate inspiration. When an inspiratory wave passes through the vagus and the respiratory center to the muscles, the center persists in this phase until the vagus signal to cut it short is received. It will be seen, therefore, that the respiratory center is activated by the gas content of the blood; and that the vagus is activated by the physical expansion and contraction of the pulmonary air cells (Seldin).

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Case Reports

This month two polycystic lesions of the mandible are presented by Dr. W. H. Hyde.

Case reports for this department should be sent to Kurt H. Thoma, 53 Bay State Road, Boston, Mass.

CASE REPORT NO. 29

POLYCYSTIC LESIONS OF THE MANDIBLE

William H. Hyde, D.D.S., F.I.C.A., Brooklyn, N. Y.

A YOUNG woman, Mrs. S. B. F., 26 years of age, born in the United States, presented herself with the following history:

History.—She had had a marked swelling on the left side of the face for the past few months. The patient visited her dentist who took an x-ray of the left mandible and found a very suspicious area. This condition progressively became worse. The pains were intermittent in character, and the

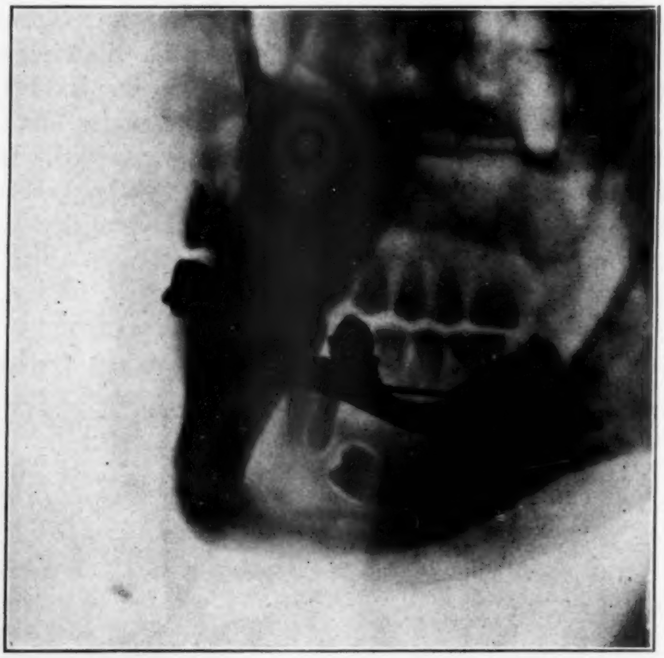

Fig. 1.

swelling would come and go. At no time were there any fistulous openings on either the buccal or external surfaces and never was there any discharge of pus from this swelling. The teeth were extracted many years prior to the onset of her complaint. She had been wearing a lower partial denture for

the past five years. Her teeth were at no time in a healthy condition. It seemed that they were always becoming carious, and they were gradually extracted. At the present time she has no teeth in her mouth.

Examination.—The patient had a marked distention of the jaw on both the buccal and lingual aspects. Intraorally, the mucous membrane was normal in character. There was a marked distention of the periosteum and a slight swelling of the left side of the mandible. There also was slight adenopathy on the left side, and periodically the face was markedly swollen. There was pain of neuralgic character, and when the swelling disappeared, the pain ceased.

A Wassermann was negative; a differential blood count was within normal limits except for the white count which was approximately 10,000; her urine was negative, and the smear of her mouth negative.

Roentgen Examination.—A large polycystic change was seen extending from one side of the mandible to the other. There was an unerupted premolar embedded in the jaw on one side, the crown of which protruded into the cystic area.

Diagnosis.—Multilocular follicular cyst.

CASE REPORT NO. 30

The patient, F. T., married, a white male, aged 62 years, born in England, a bartender, presented with the following history:

History.—For the last few years he noticed that the left side of his face had become enlarged. During this entire interval of time he had had no pain. Periodically he would have neuralgic pain in the teeth on both the right and left sides. Accordingly, he visited his physician who advised that he take sedatives and made a diagnosis of trifacial neuralgia. At the present time he had a great deal of pain in the muscles of his wrists, and his physician had been giving him all forms of pills and physiotherapy. He then advised an x-ray examination of the teeth suspecting a dental focus.

Examination.—There was marked distention of the periosteum; the adenopathy was slight. His urine was negative, and his differential blood count was as follows: hemoglobin 84 per cent; red blood cells, 4,000,000; white blood cells, 11,800; polymorphonuclear leucocytes, 71 per cent. The rest of the blood examination was within normal limits. The increase in white blood cells might be blamed on the infection of the cyst. After two weeks the white count showed a marked decrease in white cells, namely, 7,200, and an increase in the red blood count, the rest of the picture being the same.

Roentgen Examination.—The x-ray examination revealed a radiolucent area, and the patient was then referred to the writer. X-rays taken by me revealed a large radiolucent area in the mandible extending from the molar on the right side to the molar on the left side. It showed a retained canine, extending to the inferior border of the mandible, as shown in Figs. 2 and 3. Impression: dentigerous cyst.

Treatment.—I performed a cystectomy under novocain anesthesia. There was a distinct separate cyst enmeshing the retained canine. I also found a cyst extending from the lateral incisor on the left side to about the premolars

on the right side, and another extending to the molar. Toward the superior border of the mandible there was still another small cyst making me think of a multilocular cyst. The lesion did not resemble an adamantinoma clinically. The cyst was infected and contained thick brownish exudate with cholesterin crystals, that seemed cheesy in texture. The walls separating the cysts appeared very thin, and the inner aspect of the bone was smooth as those found in a solitary cyst. The inferior border of the mandible on both the right and left sides was intact following the removal of the cyst sacs.

Fig. 2.

Fig. 3.

Postoperative Diagnosis.—Multilocular follicular cysts.

Follow-up Notes.—Postoperatively the patient encountered very little pain, swelling, or discomfort. At the present writing the pains in his wrists are somewhat better, and it seems that this infected cyst may have acted as a dental focus and was responsible for his pains.

Department of Orthodontic Abstracts and Reviews

Edited by

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Malposed Canines. By Dr. Karel Wachsman, *Ceska Stomatologie,* June, 1939.

The writer classes the frequent anomalies of the maxillary canines as (1) those of primary (idiopathic) and (2) those of secondary origin. Primary anomalies are marked by congenitally irregular inclineation of the axis of the canine tooth, the latter erupting irregularly, generally mesiopalatinally, whereas the space for the canine may remain preserved or it may secondarily close up. In secondary anomalies, in which the canine always lies vestibularly, there is an inadequacy of room due either to collapse of the arch, to retrusion of the incisors, to mesial movement of the molars, or to a combination of all these causes. The mesial movement of the maxillary molars has hitherto been explained by prematurely lost deciduous molars and by mesial movement of the first permanent molar. However, cases are in no way infrequent which show the first molar in regular occlusion, while the first premolar erupts mesially, thereby occupying the room destined for the canine tooth. The cause of such mesial movement of a first premolar is to be seen in the second deciduous molar being either too wide or having its distal root enlarged in a shovel-like form; or, in the majority of cases, there exists a primary mesial inclination of premolars as the writer has found in his cases.

Treatment: In case the anomaly is due to a mesial movement of the premolars the writer recommends the following: If the first molar is still in normal occlusion, to prevent its mesial movement either by means of an arch or a plate and to extract the second deciduous molar before its proper time (if the latter is too wide) and finally to pull the first premolar distal into correct occlusion either by means of a ligature or a spring attached to the plate. However, if the first molar also has already moved mesially and the space is closed, the best solution is to extract the first premolar and to pull the canine into the space obtained in this way.

As regards retained canines the writer never forces them into proper occlusion by violent means but simply excises the mucous membrane if necessary by trepaning the bone and denuding the crown as far as its widest plane. A tooth laid bare in this manner very rapidly erupts of its own accord. This is the most biologic method of tooth movement. Only after the tooth has sufficiently erupted does the writer use artificial means to bring it into proper occlusion, either by ligature or by a spring in combination with a lingual arch or vulcanite plate appliance.

Stabilization of Treated Cases. By Harold G. Watkin, L.D.S. *The Dental Record* **59**: 355, 1939.

Watkin discusses the retention of treated orthodontic cases in a more or less unique manner. In order to explain his theory he asks us to imagine the alveolar bone as consisting of a very viscous liquid. The definition of a liquid is that substance which will take the shape of the vessel into which it is put and will finish up with a flat top surface. There are different kinds of liquids; some are mobile like water and others viscous as pitch. Now black, apparently solid, pitch is a liquid. It is only that the time factor is a long one. If an irregular piece of pitch is placed in a vessel and left for six months, it will gradually take the shape of the containing vessel.

If we could imagine a cylinder of a slightly lighter material being slowly moved through the pitch, such material will remain in its new position when its propelling force is removed unless another force is applied to it.

If a tooth is moved in a similar way by an externally applied force, we must be quite sure that in moving the tooth (or teeth) we are not creating an opposing force which, after the removal of the applied force, will compel the moved tooth to return to its original position. An example of this is the overexpansion of the dental arch which pushes the lateral series of teeth hard against the cheeks and away from the influence of the tongue. These teeth will return to their original position of equilibrium (apart from natural growth) after the removal of the expanding force. Another example is the twisting into line of a rotated incisor. The twisting pushes the teeth on either side of it apart and this winds up a force which will compel the straightened teeth to relapse.

The alveolar bone supports the teeth as water supports a boat, but does not hold them in position. The teeth are held in position by other forces, e.g., opposed muscular forces, contact points, occlusal planes, etc.

If the orthodontist will keep a clear conception of the properties of alveolar bone, he will be in a good position to make a reliable prognosis. Lack of this conception leads to relapse and failure. If the teeth are spaced this is usually a sign that the tongue is either overactive or too large, and if the teeth in such a case are closed together with an appliance, relapse is almost certain to follow the removal of the appliance. The treatment which is likely to be successful is to reduce the outward pressure of the tongue. This can easily be done according to the author, by taking a wedge-shaped piece out of the tongue.

In reply to the question as to what the author would do in cases of microglossia or where expansion is necessary, the advice was given that the arch size should then be reduced by extraction. Speech was not affected by excision of a part of the tongue.

The Use of Vitallium as a Material for Internal Fixation of Fractures. By W. C. Campbell, M.D., and J. S. Speed, M.D., Philadelphia. *Ann. Surg.* July, 1939.

Vitallium was first used in the manufacture of dentures, where resistance to infection and corroding secretions was essential. Its negligible electrolytic action, as proved by the lack of inflammation in the tissues about these plates, and the

absence of absorption of bone about the screws, has made vitallium a dependable material for the fixation of fractures even in the presence of gross infection. It is not contended that the use of vitallium for internal fixation in infected compound fractures will prevent the spread of infection of the sequestration of devitalized portions of bone. Both experimental and clinical evidence, however, indicate that vitallium will aid in reducing these complications to a minimum, and that the screws will hold the plate firmly in position, preventing displacement of the bone fragments until union is firm.

Relation of Vitamin D and Mineral Deficiencies to Dental Caries. By G. F. Taylor and C. D. M. Day. *British Medical Journal,* London **1**: 907, 1939.

Taylor and Day determined the vitamin D deficiencies and dental caries in ten cases of severe clinical rickets, with x-ray confirmation. Fifty children with rickets were examined clinically and dentally. A low incidence of dental caries and hypoplasia was observed. Ten of these children were examined roentgenologically; the teeth of four of these had no caries; and in the six other children a total of fourteen cavities was found. There were in the group ninety-six temporary teeth and 135 permanent teeth. Two cavities were found in the ninety-six temporary teeth and twelve cavities in the permanent teeth.

The diet of these children consisted mainly of carbohydrates with relatively small proportions of protein and fat. Meat and fruits were almost entirely absent from the diet. Small quantities of milk and vegetables were consumed. Sugar was rarely eaten. Only two meals were eaten daily, of rice and "chapatti." Rickets and osteomalacia were very common in the population.

On the basis of the investigation the authors conclude that vitamin D deficiency alone does not cause either dental caries or hypoplasia of the teeth. Both the teeth and jaws of this group of children were excellently formed. This low incidence of caries with excellent teeth and jaw formation is evidently characteristic of the peasant of the Punjab. In another investigation of 800 school children, made in the city of Lahore of the Indian "middle class," having a diet more in keeping with European standards, including soft refined carbohydrates and sugar, eaten three or four times daily, the incidence of caries was much higher than in the rickets cases. An average of six cavities per child was tabulated for the 800 children. In another group of twenty-six poor Indian children in an orphanage in Lahore, consuming a diet resembling that of the Kangra children, the incidence of caries was 2.27 cavities per month. Eight of the twenty-six children had no caries.

The low caries incidence of children in the Kangra District and in the orphanage, together with the physical nature of the food eaten, lends support to the "detergent diet" theory of Wallace, who claims that the physical nature and cleansing action of the diet is of more importance than other factors in the prevention of dental caries. Furthermore, sepsis and the exanthems of childhood would seem to be more potent factors in the causation of hypoplasia and caries than vitamin D and mineral deficiencies.

Secondary Impaction of a Second Deciduous Molar. By J. Beecher and G. Ginestet. Paris, *Rev. de Stomatologie* **41**: 82, 1939.

The authors report a case of a boy 9 years 6 months of age whose maxillary right second deciduous molar was apparently missing; the maxillary right first premolar and right first molar had erupted and had drifted toward one another. A roentgenogram revealed the second deciduous molar whose roots had resorbed, below the alveolar mucosa. The maxillary right second premolar was in position right above the impacted or submerged maxillary right second deciduous molar. The submerged crown of the second deciduous molar was extracted and the second premolar brought into position.

The foregoing is presented as a case of secondary impaction of a deciduous tooth. But actually, this is a case of submergence rather than impaction because the tooth had already appeared in the mouth and then all but lost contact with the oral milieu because of secondary influences. The submerged tooth rests under the mucosa and is not enclosed by alveolar bone.

Two conditions are necessary in order to produce secondary enclosure:

1. The second deciduous molar does not reach a normal state of crown eruption and occlusion as is found in the adjacent teeth.

2. After the eruption of the first permanent molar, the second deciduous molar is caught by the bulging sides of the adjacent teeth. Through the gradual progress and pressure toward eruption of the second permanent molar, the force of mastication and the resistance offered by the first deciduous molar and first premolar, increased pressure is brought on the already partly submerged second deciduous molar.

The adjacent teeth continue to drift toward each other, and the second deciduous molar is gradually forced below the alveolar mucosa and becomes an obstacle to the eruption of the second premolar.

Treatment consists of the extraction of the submerged crown and opening of the space to allow for the eruption of the permanent tooth.

"Curses on Authordonshur"

The following letter was received at a private school for dental mechanics in New York City:

Gentlemen:

Please send me all information regarding curses on authordonshur work (*sic*).

Your immediate reply would be greatly appreciated.

Very truly yours,

Dr. H. S.

And so the art of orthodontics is making great strides. Not only is it being practiced by some who know nothing about it, but it is attracting also those who cannot even spell it.

Editorial

Modern Methods for Orthodontic Lay Education

THERE has been a recent trend for popular magazines to welcome well-written and interesting articles on the subject of dental health problems. This was evidenced in the splendidly illustrated matter which recently appeared in *Life* magazine, the magazine, incidentally, reaching a very large circulation. An article on the subject appeared in the May issue of *McCall's Magazine;* in February, 1939, the *Canadian Home Journal* published an interesting article entitled "Look After Your Teeth."

The monthly periodical *Parents' Magazine* for September, 1939, reaching the newsstands at about the time this is written (August 25) will publish a timely article for parents on the subject of orthodontics entitled "Make Way for Straight Teeth!"

This favorable publicity is particularly welcome now by the dental profession on account of the changes that are ahead. It is a result of much cooperation on the part of organizations and individuals who have a broad view of professional practice and public health of the future and of lay magazines which are alert to the news, public interest, and educational value of such material.

In New York there is what is known as the Greater New York Bureau of Dental Information. This is supported by funds from the First District Dental Society, The Second District Dental Society, the New York Academy of Dentistry, and the New York Greater Dentistry Meeting. Each of these four organizations has one or two representatives on the committee, and each annually pays a small amount for the necessary expenses and for the employment of an expert in this kind of work.

In conjunction with the above setup there is in New York City the executive committee of the Bureau of Publicity of the American Association of Orthodontists. The article which is to appear on the subject of orthodontics in *Parents' Magazine* was referred to the executive committee who painstakingly edited the article in order to eliminate any misleading statements of fact that might be included within the text.

The Public Relations Bureau of the American Association of Orthodontists, in other words, is rapidly getting into action in a substantial and cooperative way with those who desire educational material.

The subcommittees of the Public Relations Bureau of the A. A. O., which held its first meeting on June 5 (for personnel see July issue of the AMERICAN JOURNAL OF ORTHODONTICS AND ORAL SURGERY, page 671), have employed Mr. Dwight Anderson, who is director of the Public Relations Bureau of the Medical Society of the State of New York, to assist in correlating these matters.

This committee as its next effort expects to distribute something like 50,000 reprints of the *Parents' Magazine* article—to parent-teacher associations, nursing associations, and all who take leadership in child welfare movements.

The Public Relations Committee of the A. A. O. should receive the enthusiastic support of orthodontists everywhere. Marked copies of *Parents' Magazine* for September should be placed in every orthodontist's office in the world. It is interesting to note as well that the fall issue of *You* magazine will carry an article authorized by the fast-moving Greater New York Bureau of Dental Information.

Orthodontics seems now on its way to receive the recognition as a department of oral health that it so justly deserves.

H. C. P.

News and Notes

British Society for the Study of Orthodontics

A meeting of the British Society for the Study of Orthodontics will be held Oct. 2, 1939, at Manson House, 26 Portland Place, W. I., London, England. Dr. Matthew Young and Miss K. Corisande Smyth will discuss "Postnormal Occlusion."

Chicago Dental Society

The Chicago Dental Society will hold its 1940 midwinter meeting February 12 to 15, inclusive, at the Stevens Hotel, according to an announcement by Dr. Harold W. Welch, president.

Great Lakes Association of Orthodontists

The thirteenth annual meeting of the Great Lakes Association of Orthodontists will be held at the Dearborn Inn, Dearborn, Mich., on Nov. 6 and 7, 1939.

OFFICERS OF ORTHODONTIC SOCIETIES*

American Association of Orthodontists

President, William A. Murray - - - - - - - - - - - - - - - - - - - Evanston, Ill.
Secretary-Treasurer, Claude R. Wood - - - - - - - - - - - - - Knoxville, Tenn.

Central Association of Orthodontists

President, Max E. Ernst - St. Paul, Minn.
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President, Ira A. Lehman - Detroit, Mich.
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Secretary-Treasurer, M. Bagley Walker - - - - - - - - - - - - - - - Norfolk, Va.

Southwestern Society of Orthodontists

President, J. H. Weaver - Houston, Texas
Secretary-Treasurer, R. E. Olson - - - - - - - - - - - - - - - - - Wichita, Kan.

Pacific Coast Society of Orthodontists

President, Will G. Sheffer - - - - - - - - - - - - - - - - - - San Jose, Calif.
Secretary-Treasurer, Earl F. Lussier - - - - - - - - - - - - - San Francisco, Calif.

American Board of Orthodontics

President, Harry E. Kelsey - - - - - - - - - - - - - - - - - - - Baltimore, Md.
Secretary, Charles R. Baker - - - - - - - - - - - - - - - - - - - Evanston, Ill.
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William E. Flesher - - - - - - - - - - - - - - - - Oklahoma City, Okla.
Frederic T. Murlless, Jr. - - - - - - - - - - - - - - - Hartford, Conn.
Oliver W. White - Detroit, Mich.
James D. McCoy - - - - - - - - - - - - - - - - - - Los Angeles, Calif.

Foreign Societies†

British Society for the Study of Orthodontics

President, S. A. Riddett
Secretary, R. Cutler
Treasurer, H. R. Evans

*The Journal will make changes or additions to the above list when notified by the secretary-treasurer of the various societies. In the event societies desire more complete publication of the names of officers, this will be done upon receipt of the names from the secretary-treasurer.

†The Journal will publish the names of the president and secretary-treasurer of foreign orthodontic societies if the information is sent direct to the editor, 8022 Forsythe, St. Louis. Mo., U. S. A.